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STRIPPABLE COAL DEPOSITS
ON
STATE LAND,
POWDER RIVER COUNTY, MONTANA

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by

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Errata--Montana Bureau of Mines and Geology Bulletin 66, Ground Water Resources of the Northern Powder River Valley, Southeastern Montana, by O. James Taylor:

Page 18, first column, next line above last, for accelebration read acceleration.

Plate 1, explanation. Under Structure contour, for data read datum.

Under lower well symbol, lower right, for Depth of well,
in feet below land surface read Altitude of bottom of well, in feet
above msl.

FOREWORD

One of the important functions of the Montana Bureau of Mines and Geology is to foster the development of mineral resources in the state. In line with this responsibility, the Bureau held a Coal Resources Symposium in October of 1964. The symposium brought into focus the tremendous magnitude of the state's coal resources and the fact that new uses for coal would again bring coal mining back as one of the state's important economic activities.

Following the symposium, support for increased research in coal was almost immediate, as the 1965 Legislature appropriated \$30,000 for expanded research in coal. This support was continued by the 1967 Legislature. Another result of the symposium was the organization of the Coal Resources Research Council, comprising members from Montana Tech, Montana State University, University of Montana, several state agencies, legislators, and representatives of private industry. Not only has the Council supported expanded research in coal, but in 1966 it drafted a strip coal-mined land reclamation bill, which was passed by the State Legislature in 1967. The Bureau was given the responsibility of entering into and enforcing provisions of contracts with strip coal-mine operators.

Research activities under the aegis of the Council include field evaluation of strippable coal resources by the Montana Bureau of Mines and Geology, chemical research in coal derivatives at Montana State University, and field and laboratory research in coal at the University of Montana.

Future use of Montana's coal depends on its competitive position in respect to other fuels. The objective of the Bureau's field-evaluation projects is to add to the identified strippable coal deposits--those which can be mined in the most economic fashion.



Associate Director

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ABSTRACT

The mapped area lies in the central western part of Powder River County east of the Tongue River and west of the Powder River. Stratigraphically, the mapped strippable coal deposits lie in the lower part of the Tongue River Member of the Fort Union Formation. In all, seven major coal beds and some local coal beds were mapped. Eight localities in three of these coal beds are suitable for strip mining.

The strippable deposits all consist of coal beds at least 12 feet thick. On Otter Creek the coal in the Knoblock bed reaches a thickness of 47 feet. The rank of the coal in the mapped area ranges from lignite to sub-bituminous C and the coal has a low ash and sulfur content. The overburden consists mainly of friable sandstone, soft gray claystone, and a few thin beds of well-indurated sandstone and limestone.

Each strippable deposit was mapped to a limit 150 feet of overburden as maximum. Strippable coal reserves total 1,472,000,000 tons and occur in the Broadus, Knoblock, and Pawnee coal beds.

INTRODUCTION

In recent years, greatly increased attention has been given the vast coal resources of the Fort Union Formation, which covers large areas in eastern Montana, western North Dakota, north-central and northeastern Wyoming, northwestern South Dakota, and southern Saskatchewan. Present and projected future demands for electric power and new sources of pipeline gas, synthetic fuels, and chemicals have created spirited competition in leasing of large strippable coal deposits, particularly in Wyoming, Montana, and North Dakota.

Much of the national interest directed to this area is due to the tremendous quantity of the coal resource. Montana alone, by conservative estimates, has a coal resource reserve of 222 billion tons, or 13 percent of the total coal resources of the United States (Bateman, 1966; Averitt, 1965; Combo and others, 1949). The coal in the Fort Union Formation in eastern Montana ranges in rank from lignite to subbituminous coal and in heating value from 7,000 to 9,000 Btu on the "as received" basis. Generally, the lower rank coal occurs along the North Dakota boundary and the higher rank coal near the Wyoming boundary (Gilmour and Dahl, 1967; Averitt, 1965, 1966). Recent work in Montana by private industry, by federal agencies, and by the Montana Bureau of Mines and Geology indicates that reserves of coal mineable within today's stripping limits exceed 8 billion tons (Groff, 1967, p. 8), and that many of the strippable coal beds are as much as 40 feet thick. Additional strippable reserves were subsequently added to this total by the work of the Northern Pacific Railway Company and the Montana Bureau of Mines and Geology during the 1967 field season. By the fall of 1971 it is expected that 15 billion tons of strippable coal will be outlined.

Coal production has increased in the western states during the last few years owing to an expanding electric power market. Nationally, power requirements have increased 8 percent every year, almost doubling every 10 years. Although the growth has not been this great in Montana, coal production in the state will more than double when the Montana Power Company new 180,000 kw plant at Billings is in full operation in 1968. The company projects that 2 million tons of coal will be required annually by 1980 to fulfill its power requirements (Schmechel, 1967). By that time, large-scale plants for the conversion of coal to pipeline gas, synthetic fuels, and chemicals are expected to be in production, utilizing additional millions of tons of coal.

Potential industrial development based on coal as the raw material is limited only by availability of water. At the present time, the Yellowstone River contains the largest source of available water supply near the study area. Its tributary, the Powder River, would have potential if a reservoir were constructed at a site proposed by the Bureau of Reclamation near

Moorhead. Moorhead dam, originally proposed as a multipurpose dam for irrigation, flood control, recreation, and power generation, would be feasible if large amounts of water were sold for industrial use.

PURPOSE AND SCOPE

This report was prepared as part of the program of the Montana Bureau of Mines and Geology in coal resources research. Increased interest in Montana's coal resources, coupled with an expanding coal industry, prompted the state to increase its activity in evaluation of coal resources and in gathering information useful to industry in exploration and development. This report outlines information on selected state coal land in Powder River County.

The Montana Bureau of Mines and Geology had two field crews working on separate coal-mapping projects in Powder River County during the summer of 1967. One crew worked on mapping strippable coal deposits as a cooperative project with the Northern Pacific Railway Company, and the other crew mapped strippable coal on state land. This second project is discussed in this report.

LOCATION

All of the state lands described in this report are in the central and western parts of Powder River County, in an area bordered on the east by the Powder River and on the west by the divide between Otter Creek and the Tongue River south of Ashland. The locations of these state sections are indicated on Figure 1.

FIELD WORK AND ACKNOWLEDGMENTS

T. E. Finch of the Montana College of Mineral Science and Technology assisted in the Otter Creek area. Loren Williams, mining engineer, Northern Pacific Railway Company, made many suggestions that assisted in the field work.

U. M. Sahinen, associate director of the Montana Bureau of Mines and Geology, and S. L. Groff, chief, Ground Water and Mineral Fuels Division, organized this coal research program.

PREVIOUS GEOLOGIC WORK

All of that portion of Powder River County covered by the Fort Union Formation has been investigated by the U.S. Geological Survey. The results of these studies are presented in the following publications: The Ashland Coal Field (Bass, 1932), The Coalwood Coal Field (Bryson, 1952), Strippable Coal in Custer and Powder River Counties (Brown and others, 1954),

Reconnaissance Geology of the Birney-Broadus Coal Field (Warren, 1959), and Geologic Map of Coal Sections of the Moorhead Coal Field (Bryson and Bass, 1966). In addition, the Northern Pacific Railway Company and the Montana Bureau of Mines and Geology mapped strippable coal reserves in the Foster Creek deposit in 1966 and in the Broadus deposit, the Sand Creek deposit, and the Poker Jim-Odell Creek deposits in 1967.

An index map (Fig. 2) shows the areas described in the published reports and cooperative mapping programs listed above, as well as similar studies in the region.

GEOGRAPHY

SURFACE FEATURES AND LAND USE

The area included in this report lies in the Great Plains physiographic province and is located on the eastern flank of the Powder River Basin. The topography is characterized by deeply dissected badlands, high clinker-topped buttes and ridges, and broad rolling uplands. The land is presently utilized principally for stock raising. Dryland farming is carried out wherever the terrain permits. Intensified farming is conducted along the subirrigated valleys of the Powder River, Pumpkin Creek, and Otter Creek. The strip-pable coal deposits mapped on this project all lie within the valleys.

DRAINAGE AND WATER SUPPLY

The area is drained by the northward-flowing Powder and Tongue Rivers, which join the Yellowstone River near Terry and Miles City, respectively. The Powder River and its tributary, Mizpah Creek, drain the eastern and northeastern part of the area. The northern and western parts of the area are drained by Pumpkin Creek and by Otter Creek, both tributaries of the Tongue River.

The highest period of discharge in the major drainages normally occurs during the spring runoff in May and June. All of the major drainages except the Tongue River have periods of no flow. The Powder River has been subject to flooding during periods of heavy precipitation. The tributary drainages are intermittent streams flowing only during the spring thaw or during periods of heavy precipitation.

Gaging stations of the U. S. Geological Survey are on the Powder River near Moorhead, at Locate, south of Terry in Custer County, and on the Little Powder River near Broadus. On the Tongue River the gaging stations are at Decker, below Tongue River dam, and near Miles City. Sites for collecting data on quality of water are at Decker and near Miles City on the Tongue River (Table 1).

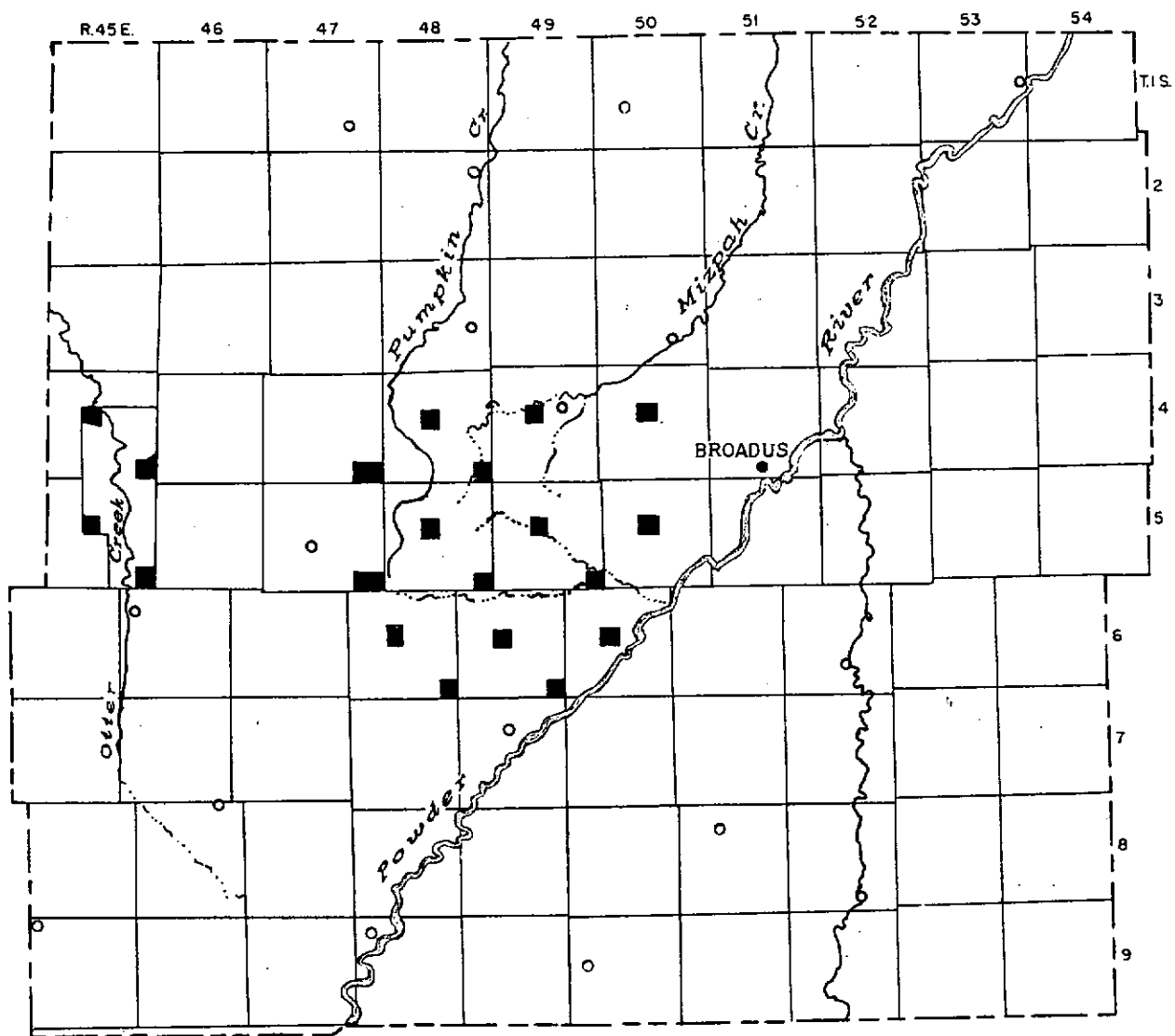


Figure 1. --Index map of Powder River County showing location of state lands investigated in this report.

Table 1.--Average discharge and rate of flow of Tongue River and Powder River.*

River	Gaging station	Average annual discharge (ac-ft)	Discharge extremes (cfs)	
			max.	min.
Powder	Locate ^{1/}	423,500	31,000	0
Powder	Moorhead ^{2/}	317,800	23,000	0
Little Powder	Broadus ^{3/}	22,010	2,340	0
Tongue	Miles City ^{4/}	267,900	13,300	0
Tongue	Tongue River dam ^{5/}	306,200	6,180	0.5
Tongue	State line (Decker) ^{6/}	304,800	6,080	3.9
Yellowstone	Miles City ^{7/}	7,884,000	96,300	996

^{1/} Avg. 28 yr. (1938-66)

^{2/} Avg. 37 yr. (1929-66)

^{3/} Avg. 14 yr. (1947-53, 1957-61, 1962-66)

^{4/} Avg. 23 yr. (1938-42, 1946-66)

^{5/} Avg. 27 yr. (1939-66)

^{6/} Avg. 6 yr. (1960-66)

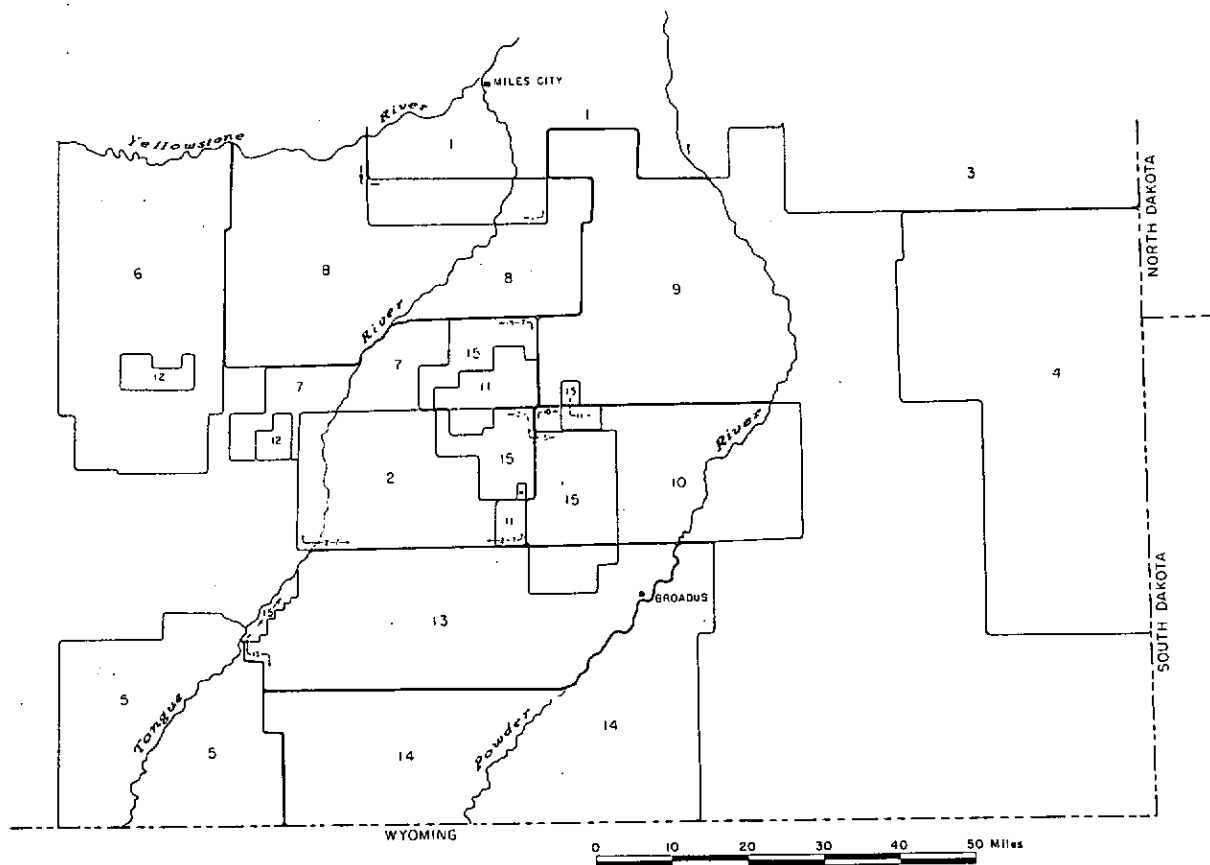
^{7/} Avg. 39 yr. (1922-23, 1928-66)

*Source: 1966 Water Resources Data for Montana, Pt. 1, Surface Water Records: U.S. Geol. Survey.

The Tongue River reservoir, in T. 8 and 9 S., R. 40 E., has a present storage capacity estimated at 68,000 acre-feet. Of this amount, 32,000 acre-feet is under contract for irrigation, and a proposed new contract calls for increasing irrigation water to 35,000 acre-feet. Additional water from the existing reservoir is available for sale, but the exact amount is not known (Darlinton, 1968, personal communication).

The Montana Water Resources Board retained a private consulting firm in 1967 to make a complete study of the water supply and potential reservoir sites on the Tongue River. Preliminary indications are that Montana is entitled to 100,000 acre-feet of firm yield annually from the Tongue River, which would provide 65,000 acre-feet for purposes other than irrigation. However, to obtain this yield, it will be necessary to construct another reservoir with a 320,000 acre-foot storage downstream from the present reservoir (Darlinton, 1968, personal communication).

Although no dams have been built on the Powder River, the Bureau of Reclamation (Drazich, 1968, unpublished paper) has proposed construction of Moorhead dam a few miles north of the Montana-Wyoming border near Moorhead. The proposed reservoir would have a capacity of 1,150,000 acre-feet, divided as follows:



1. 1909. Collier, A. J., and Smith, C. D., The Miles City coal field, Montana: U. S. Geol. Survey Bull. 341-A, p. 36-61.
2. 1910. Wegemann, C. H., Notes on the coals of the Custer National Forest, Montana: U.S. Geol. Survey Bull. 381-A, p. 108-114.
3. 1912. Bowen, C. F., The Baker lignite field, Custer County, Montana: U. S. Geol. Survey Bull. 471-D, p. 202-226.
4. 1924. Bauer, C. M., The Ekalaka lignite field, southeastern Montana: U. S. Geol. Survey Bull. 751-F, p. 231-267.
5. 1929. Baker, A. A., The northward extension of the Sheridan coal field, Big Horn and Rosebud Counties, Montana: U.S. Geol. Survey Bull. 806-B, p. 15-67.
6. 1930. Dobbin, C. E., The Forsyth coal field, Rosebud, Treasure, and Big Horn Counties, Montana: U. S. Geol. Survey Bull. 812-A, p. 1-55.
7. 1932. Bass, N. W., The Ashland coal field, Rosebud, Powder River, and Custer Counties, Montana: U. S. Geol. Survey Bull. 831-B, p. 19-105.
8. 1936. Pierce, W. G., The Rosebud coal field, Rosebud and Custer Counties, Montana: U. S. Geol. Survey Bull. 847-B, p. 43-120.
9. 1939. Parker, F. S., and Andrews, D. A., The Mizpah coal field, Custer County, Montana: U.S. Geol. Survey Bull. 906-C, p. 85-133.
10. 1952. Bryson, R. P., The Coalwood coal field, Powder River County, Montana: U.S. Geol. Survey Bull. 973-B, p. 23-106.
11. 1954. Brown, Andrew, and others, Strippable coal in Custer and Powder River Counties, Montana: U. S. Geol. Survey Bull. 995-E, p. 151-199.
12. 1954. Kepferle, R. C., Selected deposits of strippable coal in central Rosebud County, Montana: U. S. Geol. Survey Bull. 995-I, p. 333-381.
13. 1959. Warren, W. C., Reconnaissance geology of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana: U. S. Geol. Survey Bull. 1072-J, p. 561-585.
14. 1966. Bryson, R. P., and Bass, N. W., Geologic map and coal sections of the Moorhead coal field, Montana: U. S. Geol. Survey Open-File Rept., 37 fig., 3 tables, in 15 sheets.
15. ---- Northern Pacific Railway Company cooperative projects with the Montana Bureau of Mines and Geology in 1966 and 1967.

Figure 2. --Index map to coal studies in southeastern Montana.

Inactive and silt storage	625,000 acre-ft
Conservation	275,000 acre-ft
Flood control	<u>250,000 acre-ft</u>
Total	1,150,000 acre-ft

The industrial plan for Moorhead reservoir would provide a firm supply of 92,500 acre-feet annually, of which 50,400 acre-feet would be allocated to Wyoming and 42,100 acre-feet to Montana.

Except for the Powder River and Otter Creek, very little surface water is available in the area. The largest amount of water for domestic, livestock, and agricultural use is obtained from wells. An inventory of water wells, compiled by the Ground Water Branch of the Montana Bureau of Mines and Geology, totals 1,934 wells drilled in Powder River County. Of this total, 1,519 are utilized for livestock, 202 for domestic and livestock purposes, 169 for strictly domestic purposes, and 20 for irrigation. The other wells are used for commercial, industrial, and public water supplies.

The principal sources of ground water in the area are the alluvium along the drainages and the sandstone and coal beds in the Fort Union and Hell Creek Formations (Perry, 1935, p. 40, 43).

During the 1967 drilling program, it was found that local deposits of clinker gravel in valleys are a good source of water. For example, in sec. 36, T. 5 S., R. 49 E., three drill holes were attempted in the Cache Creek valley about 200 feet to 300 feet north of the completed drill hole, but circulation was lost when the clinker gravels were hit at depths of 50 to 75 feet. In the completed drill hole, a water-bearing sand was intersected at a depth of 85 to 86 feet. Circulation difficulties were common during the drilling program when drill holes penetrated thin coal beds.

CLIMATE

The climate of Broadus and Powder River County is characterized by warm summers, cold winters, and pronounced variations in seasonal precipitation.

Although the average annual precipitation in Broadus is only 13.83 inches (U.S. Weather Bureau records for 24 years), it is well distributed during the growing season. The maximum precipitation falls during the months from April through September. In a 24-year period, the average June precipitation has been 3.18 inches. The total snowfall from the months of October through May averages 32.9 inches.

The highest temperatures occur in July and the lowest in January. The annual mean temperature averaged 45 degrees over a 24-year period. During that period, the July mean was 71.5 degrees and the January mean was 18.6 degrees. The maximum temperature recorded was 108 degrees and the minimum was minus 42 degrees.

POPULATION

Powder River County is one of the most sparsely populated areas of Montana. The county, which has an area of 3,285 square miles, had a 1960 population of 2,485, or a population density of 0.8 person per square mile.

Broadus, the largest community in the county, had a 1960 population of 628 persons, or about one-fourth of the total county population. If the population of Broadus is subtracted from the total county population, the rural population density is about 0.6 person per square mile.

Although the county experienced a 7.7 percent decrease in population between 1950 and 1960, this trend will be reversed as a result of the discovery of Bell Creek oil field southeast of Broadus.

POWER

Powder River County is serviced by the Tongue River Electric Cooperative with headquarters in Ashland. Power for the Broadus area is supplied by 69 kv (4-0 ACSR) line extending from Colstrip to Broadus. A new 2,500 kva substation is located in Broadus and another 1,500 kva substation is located near Epsie. Power is purchased by the cooperative from the Montana Power Company.

TRANSPORTATION

The nearest mainline railroad is at Miles City, 80 miles north of Broadus, where both the Northern Pacific and the Chicago, Milwaukee, St. Paul and Pacific railroads follow the Yellowstone River.

Broadus is served by east-west U. S. Highway 212 and by U. S. Highway 312, which extends from a point near Broadus north to Miles City. An all-weather improved graded road extends from Broadus southwest to Moorhead. An improved graveled road extends from the U. S. Highway 212 crossing of Pumpkin Creek south to Sonnette and thence west to Otter Creek. South from Sonnette, good graded roads traverse National Forest land. Otter Creek is served by a partly oiled and graveled road extending south from Highway 212; the junction is about 3 miles east of Ashland. Most of the other roads are not much more than trails providing access for farming and ranching operations.

LAND OWNERSHIP

Most of the area of this report lies south of the limit of land grants to the Northern Pacific Railway Company, under which the railroad was given title to all odd-numbered sections in each township. Although much of the original land has been conveyed to other ownership, the Northern Pacific retained all the mineral rights on most of the original land grant. Sections 16 and 36 were granted to the State of Montana as school land, and the state has generally retained all of its mineral rights. Of the even-numbered sections, much of the more accessible land was homesteaded and disposed of by the federal government. The government, however, retained its coal rights and some other mineral rights.

STRATIGRAPHY

The coal beds in the area discussed in this report are in the Tongue River Member of the Fort Union Formation. Although the age of the members of this formation has been a subject of controversy for one hundred years, it is now accepted that the three members, the Tullock, Lebo, and Tongue River, are all of Paleocene age (Brown, 1962, p. 11).

FORT UNION FORMATION

The Fort Union Formation was named by Meek and Hayden (1862, p. 433) for Old Fort Union, situated near the junction of the Missouri and Yellowstone Rivers. Specifically, this name applies to strata on the north side of the Missouri River between Snowden, Montana, and Buford, North Dakota (Brown, 1962, p. 3). Subsequent field work in eastern Montana resulted in the division of the Fort Union into three members on a basis of color, lithology, topographic expression, and occurrence of coal. Early geologists found these criteria convenient for distinguishing mappable units.

In eastern Montana, particularly along the Yellowstone River between Rosebud and Glendive, the Fort Union is divisible into its members on the basis of color alone. The dark Lebo beds contrast with the light-colored Tullock beds below and the light-colored beds of the Tongue River Member above. The color differences are not in themselves distinctive in identification of the members in all areas of eastern Montana, however. To the west, toward the source of the sediments, the dark and lower light zones lose their identity and merge into a greenish-gray or gray sandy sequence (Brown, 1962, p. 3). To the southeast and east, including the area discussed in this report, and in western North Dakota, the two lower members cannot be distinguished and are together referred to as the lower member (Bryson, 1952, p. 46-52) in Montana and the Ludlow (Brown, 1962, p. 6) in North Dakota.

The base of the Fort Union was defined by Brown (1907, p. 834) as the base of the lowest coal bed above the dinosaur-containing beds of the Hell Creek Formation, of late Cretaceous age. Subsequently, numerous writers attempted to redefine the Cretaceous-Paleocene boundary. Brown (1962, p. 11), after many years of study of this problem, concluded that use of the lowest coal as the boundary is still valid, and when paleontological evidence from above and below the zone is used where the coal does not occur, the Cretaceous-Tertiary contact can usually be closely determined.

In the type locality of the Tullock Member, in Treasure County, Rogers and Lee (1923, p. 29) described the Tullock as containing ten lenticular coal beds; they placed the base at the bottom of the lowest coal bed. The upper boundary of the Tullock, or base of the Lebo, has been described locally as the base of the "Big Dirty" coal bed (Thom and Dobbin, 1924, p. 494). Rogers and Lee (1923, p. 30) described this contact as the top of a thin but persistent sandstone, which weathers to a well-defined rimrock.

Tongue River Member, chiefly differentiated from the underlying Lebo by its color (Taff, 1909, p. 128; Collier and Smith, 1909, p. 42; Dobbin, 1929, p. 14; Rogers and Lee, 1923, p. 36; and Pierce, 1936, p. 59), contains the greatest number of coal beds and the ones of greatest thickness.

Lithologically, the greatest difference in the three members of the Fort Union Formation, where differentiated, is between the Lebo and the members underlying and overlying it. The Tullock and Tongue River Members show similarities in color, topographic expression, and lithology, being mainly light-colored fine-grained sandstone, claystone, and coal beds in an interlayered sequence. The Lebo, on the other hand, is composed of dark drab somber beds of dark-gray to olive-gray shale containing altered and devitrified volcanic ash and abundant brown ferruginous concretions (Rogers and Lee, 1923, p. 36-39).

The Lebo, owing to its relative softness and its position above the resistant cap rock of the Tullock Member, characteristically erodes to form long gentle slopes (Rogers and Lee, 1923, p. 35). In many places it forms barren badlands, smoothly rounded "haystack" knolls, and slump blocks (Badgley, 1953, p. 39). The Tullock and Tongue River Members form steep escarpments, owing to the resistant sandstones common in both. The Tongue River Member is characterized by thick layers of reddish clinker that resulted from burning of its thick coal beds.

Lower Member

The lower member of the Fort Union Formation is not exposed in the area discussed in this report, but it does crop out adjacent to it. Although the Tullock and Lebo Members have been recognized and described as distinct stratigraphic units along the Yellowstone River farther north, they

have not been differentiated in the Coalwood area (Bryson, 1952, p. 32) nor in the Birney-Broadus area (Warren, 1959, p. 564). They have been differentiated, however, in the southeastern part of Powder River County (Robinson, Mapel, and Bergendahl, 1964, p. 99-104). They are herein referred to as the lower member.

The lower member in the Coalwood field, which borders the Birney-Broadus area on the north, has been described in detail by Bryson (1952, p. 46-52). It is about 375 feet thick and consists of somber brownish-gray to gray thin-bedded sandstone, calcareous siltstone, shale, and clay, and smaller amounts of buff sandstone and shale, brown to black carbonaceous shale, and thin lenticular coal beds. Warren (1959, p. 564) described the lower member as consisting of somber brownish-gray-weathering thin-bedded sandstone, sandy shale, and lenticular coal beds less than $2\frac{1}{2}$ feet thick.

The lower member is exposed along the valley of the Powder River and covers a broad area in the vicinity of the town of Broadus. Its upper contact is near the base of the steep ridges, composed of the Tongue River Member, overlooking the valley of the Powder River west and southwest of Broadus. Owing to the gentle southwest dip of the strata, the lower member passes beneath alluvium of the Powder River valley in the southeastern part of T. 5 S., R. 50 E. (Warren, 1959, p. 564).

Table 2. --General stratigraphic units of the upper Cretaceous and Paleocene.

Paleocene	Birney-Broadus, USGS Bull. 1072-J	Coalwood field, USGS Bull. 973-B	Tullock Creek, USGS Bull. 749	Northern and western flanks Black Hills uplift, USGS Prof. Paper 404
	Tongue River Member	Tongue River Member	Tongue River Member	Tongue River Member
	Lower member	Lower member	Lebo Member	Lebo Member
			Tullock Member	Tullock Member
Upper Cretaceous		Hell Creek Formation	Hell Creek Formation	Lance Formation

Tongue River Member

The strata exposed in the area of this report are in the lower half of the Tongue River Member of the Fort Union Formation and total more than 950 feet in thickness (Fig. 3; App. 1). The base of the Tongue River Member, as described by Warren (1959, p. 564) is placed at the base of the lowermost persistent yellowish-gray-weathering sandstone about 100 feet below the base of the Broadus coal bed. Bryson (1952, p. 52) described the base at a similar horizon or at the base of the lowermost locally persistent buff-weathering sandstone or siltstone.

The lowermost persistent sandstone is well exposed in a gully east of the Peerless mine, sec. 23 and 25, T. 4 S., R. 50 E. This unit is 35 feet thick and consists of tannish-gray fine-grained subarkosic sandstone showing high-angle cross-stratification. Claystone pebbles, limestone "ribs", and altered marcasite "marbles" occur along the bedding planes.

The Tongue River Member is characterized by pale-olive to yellowish-gray fine-grained sandstone, yellowish-gray claystone, interbedded claystone and sandstone, interbedded shale and claystone, thick coal beds, and carbonaceous shale. The sandstone beds and the claystone-shale sequences occur in almost equal proportion. The sandstone beds, occurring at various stratigraphic levels, commonly form cliffs, knobs, and pinnacles. The thick coal beds of major interest in this report--the Broadus, Knoblock, and Pawnee--are widely separated stratigraphically (Fig. 3). Much of the coal originally in the area has burned, leaving thick beds of pink, red, and brown clinker.

Clinker forms resistant cappings to the buttes and ridges, maintaining steep slopes along the ridges. The term clinker includes all of the several types of rock produced by fusing and baking of strata overlying a burning coal bed. A high ridge may show at least three clinker zones where the coal beds have burned at their outcrop (Rogers, 1918, p. 1-10).

STRUCTURE

Detailed mapping of structure was not included in this study. In general, the sediments are flat lying. The base of the Broadus bed (Warren, 1959, p. 566) is 275 feet lower in the southern part of T. 5 S., R. 50 E., than in the north-central part of T. 4 S., R. 51 E., indicating a southwestward dip of less than 1 degree. During the current investigation, vertical control data indicated a broad low anticline in the Sonnette area. This may be the eastward extension of a similar structure in the Otter Creek area. Warren (1959, p. 566) mentioned an anticlinal trend across Otter Creek in

sec. 26, T. 5 S., R. 45 E., and in T. 4 and 5 S., R. 50 and 51 E., he mapped several southeast-trending faults having displacements of 40 to 125 feet.

ECONOMIC GEOLOGY

COAL BEDS

The economically important coal beds in the study area include the Broadus bed, the Knoblock bed, and the Pawnee bed. In most respects, the coal in the various beds is similar, although rank ranges from lignite to subbituminous C. Typically, fresh samples of coal are banded, brown to black, have a bright luster, and contain abundant previtrain. Previtrain is a type of coal having a bright luster and conchoidal fracture; it is derived from carbonization of single, relatively large fragments of ancient plants.

Fresh coal samples are brittle, but if wet, as exposed at creek bottoms, they may be exceedingly tough. On weathered outcrops gypsum crystals are generally abundant. Partly coalified and silicified wood was observed in several of the coal beds. Complete silicified tree trunks and stumps are abundant at the top of the Pawnee bed(?) in the NW $\frac{1}{4}$ sec. 16, T. 5 S., R. 49 E., and in the Garfield bed in the SW $\frac{1}{4}$ sec. 25, T. 6 S., R. 48 E. Partings are commonly brown to dark-brown carbonaceous shale and claystone containing abundant plant impressions and carbonized plant fragments.

Cores from two coal beds in the study area were analyzed by the U. S. Bureau of Mines Coal Research Center at Pittsburgh (Table 3). The first core was from the Pawnee coal bed on Cache Creek in the SW $\frac{1}{4}$ sec. 36, T. 5 S., R. 48 E. The second was from the Knoblock bed in the SE $\frac{1}{4}$ sec. 36, T. 4 S., R. 45 E., near Otter Creek. The rank of the coal ranges from lignite in the Pawnee bed to subbituminous C in the Knoblock bed, classified according to specifications of the American Society for Testing Materials (1964, p. 74), in which lignite and subbituminous C calorific values on a moist mineral-matter-free basis range from 6,300 to 8,300 Btu and from 8,300 to 9,500 Btu per pound, respectively.

The sulfur content of both samples is low, as is the ash content, which is typical of the coal of the Tongue River Member.

Additional analyses from previous reports are included in Table 3 to show the range and variation of composition of the coal in the general area.

Broadus Bed

The Broadus coal bed was originally mapped and named by Warren (1959, p. 561-585) in the Birney-Broadus area. He reported that the Broadus

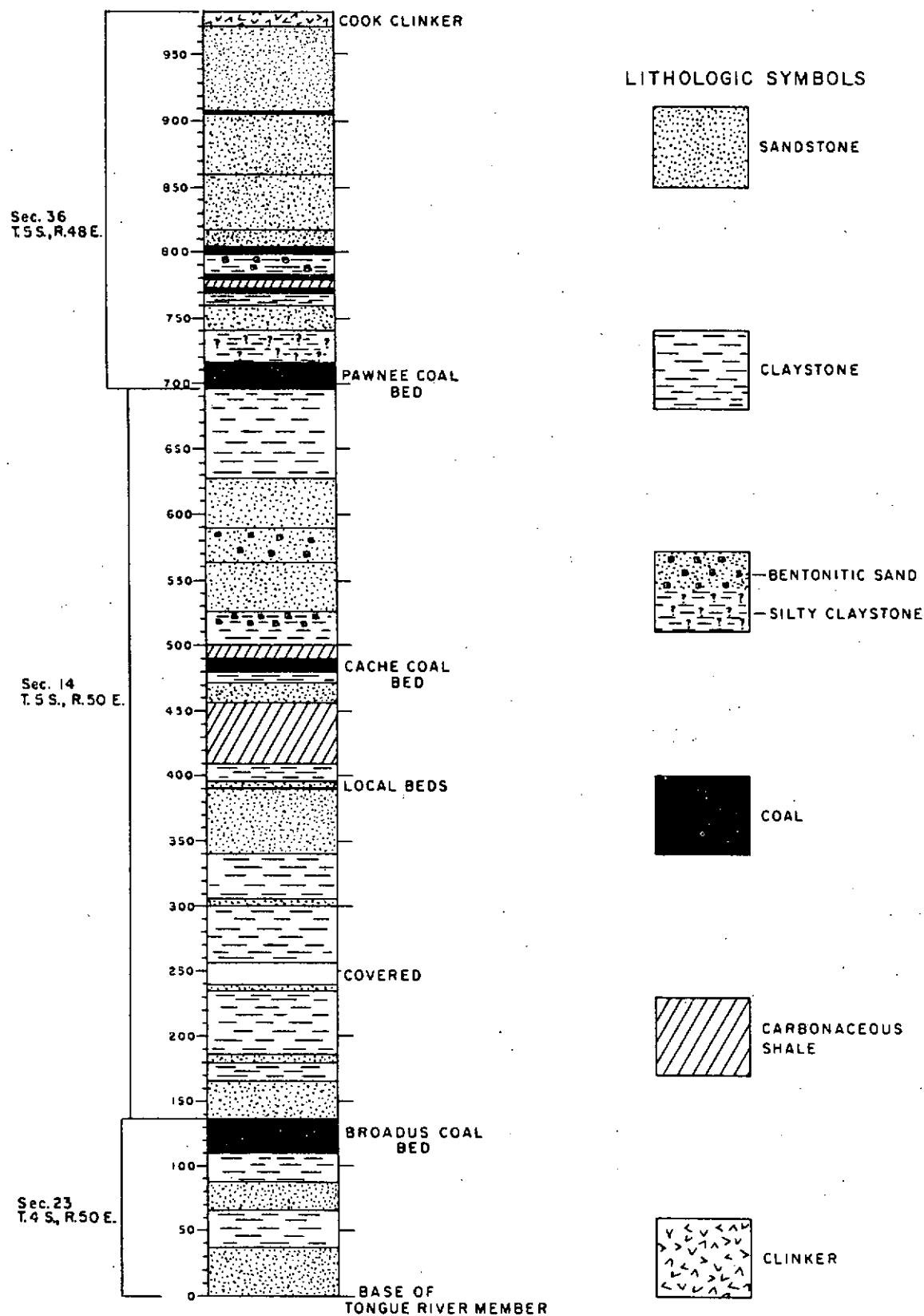


Figure 3. --Generalized stratigraphic section of the lower half of the Tongue River Member of the Fort Union Formation.

bed lies 100 feet above the base of the Tongue River Member. This distance was verified by us in a section measured near the Peerless mine. The bed was traced northward into the Coalwood field (Bryson, 1952) and its northern limit mapped a few miles southeast of the Coalwood Post Office. In the Coalwood field, however, the bed is about 135 feet above the base of the Tongue River Member. The Broadus bed underlies a large area west of the Powder River, and has been mapped east of the river by Bryson and Bass (1966).

Maximum thickness of the Broadus coal bed, as determined by the 1967 drilling program of the Montana Bureau of Mines and Geology and the Northern Pacific Railway Company, is 26 feet at the Peerless mine (sec. 23, T. 4 S., R. 50 E.). The bed maintains a thickness of at least 20 feet northward into sec. 26, T. 2 S., R. 49 E. (Fig. 3), but thins southward and westward from the Peerless mine. In sec. 36, T. 5 S., R. 49 E., on Cache Creek, the bed is 12 feet thick. The log of a water well in sec. 15, T. 5 S., R. 49 E., indicates that the Broadus bed there is 4 feet thick. In sec. 16, T. 4 S., R. 49 E., on Mizpah Creek, the Broadus bed as logged in a drill hole is 6 feet thick. The Broadus bed as drilled near the southeast corner of sec. 16, T. 6 S., R. 50 E., measured 6 feet thick, but the upper part of the coal bed was weathered, indicating that part of it may have been removed by erosion. A large part of the original coal reserve in the area paralleling north-south Highway 212, from a point near Broadus to Coalwood, has been burned.

Several analyses of coal from the Broadus bed rank it as lignite (Table 3).

The overburden on the Broadus bed at the Peerless mine consists of 6 feet of claystone and 85 feet of tan fine- to medium-grained sandstone showing high-angle cross-stratification. The sandstone, although friable, is sufficiently indurated to maintain near-vertical walls. As is typical of fluvial sediments, lateral changes are abrupt. In a section measured south of the Peerless mine near the Superior mine (sec. 14, T. 5 S., R. 50 E.), the overburden consists of interbedded fine-grained sandstone and yellowish-gray claystone (App. 1).

At the Peerless mine, the Broadus bed is free of partings except for one about 6 inches thick near the base. No partings were detected in the drill hole on Cache Creek, but in an exposure in sec. 10, T. 6 S., R. 50 E., the Broadus bed consists of two benches separated by 4 feet of claystone. The Broadus bed and overlying strata measured in this section are as follows:

<u>Feet</u>	<u>Inches</u>	<u>Description</u>
10+	0	Sandstone, fine grained, light gray to pale yellowish gray, cross-bedded, massive
3	0	Claystone, grading to sandstone, light gray to light yellowish gray; layers of ironstone concretions
0	7	Coal, abundant previtrain
0	4	Underclay, dark brown, vitreous luster
3	6	Claystone, light olive gray, slightly fissile; abundant coalified plant fragments
11	4	Coal, abundant previtrain

Pawnee Bed

The Pawnee coal bed underlies a broad area extending from the vicinity of the upper reaches of Cache Creek westward to the Pumpkin Creek area, and in various parts of this area it could be strip mined. It has been mapped by Bryson and Bass (1966) as far south as sec. 32, T. 8 S., R. 48 E., near Moorhead, where it passes beneath alluvium of the Powder River valley. Warren (1959, p. 572) reported that in T. 4 S., R. 47 and 48 E., the Pawnee bed consists of two benches 45 feet apart. Warren believed that the upper bench of the Pawnee is the same as the Dunning bed exposed in steep valley walls in the Otter Creek drainage, but the name Dunning is not used west of the Otter Creek-Pumpkin Creek divide.

The Pawnee bed is consistently about 20 feet thick throughout the upper reaches of Cache Creek and Pumpkin Creek near Sonnette. In drill holes on state sec. 16 and 36, T. 5 S., R. 48 E., it was logged at 22 feet and 20 feet respectively. In sec. 35, T. 6 S., R. 49 E., the measured thickness is 19 feet. Six miles farther west, in sec. 16, T. 6 S., R. 48 E., an incomplete section measured in the Pinto Creek drainage shows 16+ feet of coal. Analysis of a core from sec. 36, T. 5 S., R. 48 E., ranks the Pawnee bed as lignite having a Btu value of 7,650 (Table 3).

Knoblock Bed

The Knoblock bed was named (Bass, 1924) for the Knoblock ranch in T. 5 S., R. 43 E., on the Tongue River (Warren, 1959, p. 571). The bed has been traced and mapped eastward into the Otter Creek drainage (Warren, 1959), northward into the Ashland coal field (Bass, 1932), northeastward into

Table 3. --Analyses of coal from locations in and near the area discussed in this report, including four analyses of cores taken during the 1967 field season.

Source	Lab number	Air-drying loss	Form of analysis ¹	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Heating value (Btu)	Classification of coal by rank
Peerless mine	B-29378 to	25.7	A	33.9	26.6	33.1	6.4	0.2	7,240	lignite
Broadus coal bed ¹ / sec. 23, T. 4 S., R. 50 E. Powder River County	B-29381 (composite of 4)		B C D	10.9 ---- ----	35.8 40.2 44.5	44.6 50.1 55.5	8.7 9.7 ---	0.3 0.3 0.4	9,750 10,650 12,130	
Victor Stabio prospect	B-56504	19.2	A	29.0	31.6	31.3	8.1	0.3	6,390	lignite
Broadus coal bed ¹ / sec. 24, T. 4 S., R. 50 E. Powder River County			B C D	12.1 ---- ----	39.1 44.5 50.2	38.8 44.1 49.8	10.0 11.4 ---	0.4 0.5 0.5	7,910 9,010 10,160	
Black Diamond mine	C-75726	21.0	A	32.3	29.8	31.4	6.5	0.3	7,380	lignite
Broadus coal bed ¹ / sec. 11, T. 5 S., R. 50 E. Powder River County			B C D	14.3 ---- ----	37.8 44.0 48.7	39.7 46.4 51.3	8.2 9.6 ---	0.3 0.4 0.4	9,340 10,900 12,050	
Superior mine	C-75920	20.2	A	33.5	28.3	32.2	6.0	0.4	7,290	lignite
Broadus coal bed ¹ / sec. 14, T. 5 S., R. 50 E. Powder River County			B C D	16.6 ---- ----	35.4 42.5 46.7	40.5 48.5 53.3	7.5 9.0 ---	0.5 0.6 0.6	9,140 10,970 12,050	
Core sample ² / sec. 18, T. 9 S., R. 48 E. Powder River County	C-91743 to C-91744; C-92479 to C-92480 (composite of 4)	----	A B C D	28.5 ---- ---- ----	29.7 36.3 41.3 44.5	37.0 45.2 51.8 55.5	4.7 5.8 6.6 ---	0.7 0.3 0.9 1.0	8,542 10,430 11,945 12,715	subbituminous C
Core sample ² / sec. 19, T. 9 S., R. 48 E. Powder River County	C-92752 & C-92754 (composite)	----	A B C D	27.9 ---- ---- ----	30.3 36.8 42.0 45.8	35.8 43.5 49.7 54.1	6.0 7.3 8.3 ---	0.8 0.9 1.1 1.3	8,480 10,310 11,760 12,820	subbituminous C

Core sample Knoblock bed ³ / sec. 36, T. 4 S., R. 45 E. Powder River County	I-73317	----	A	26.6	29.6	38.6	5.2	0.2	8,740	subbitumi- nous C
			B	----	----	----	----	----	----	
			C	----	40.3	52.6	7.1	0.3	11,910	
			D	----	43.4	56.6	----	0.3	12,810	
Core sample Pawnee bed ³ / sec. 36, T. 5 S., R. 48 E. Powder River County	I-73316	----	A	32.0	29.5	32.5	6.0	0.2	7,650	lignite
			B	----	----	----	----	----	----	
			C	----	43.4	47.8	8.8	0.3	11,250	
			D	----	47.5	52.5	----	0.3	12,340	
Ash Creek mine Sawyer coal bed sec. 35, T. 2 S., R. 49 E	C-75916	23.1	A	35.2	30.6	30.2	4.0	0.3	6,930	lignite
			B	15.7	39.8	39.3	5.2	0.4	9,020	
			C	----	47.2	46.6	6.2	0.5	10,700	
			D	----	50.3	49.7	----	0.5	11,410	
Core sample Knoblock bed ⁴ / T. 1 S., R. 50 E. Powder River County	I-73091	----	A	31.1	27.81	32.81	8.23	0.29	7,220	lignite
			B	----	----	----	----	----	----	
			C	----	40.37	47.61	12.02	0.42	10,480	
			D	----	45.89	54.11	----	0.48	11,910	
Core sample Knoblock bed ⁴ / T. 1 S., R. 50 E. Powder River County	I-73091	----	A	32.57	28.30	34.06	5.07	0.31	7,460	lignite
			B	----	----	----	----	----	----	
			C	----	41.97	50.52	7.51	0.46	11,060	
			D	----	45.38	54.62	----	0.50	11,960	
Holt mine Terret bed sec. 10, T. 3 S., R. 44 E.	H-42289	6.8	A	27.3	27.5	41.3	3.9	0.4	9,020	subbitumi- nous C
			B	22.0	29.5	44.3	4.2	0.4	9,680	
			C	----	37.8	56.8	5.4	0.6	12,400	
			D	----	40.0	60.0	----	0.6	13,100	

1/ Reconnaissance geology of the Birney-Broadus coal field, Rosebud and Powder River Counties, Montana, by W. C. Warren: U.S. Geol. Survey Bull. 1072-J.
 2/ U.S. Geol. Survey open-file rept. on Moorhead dam, Powder River County, Montana.
 3/ Montana Bur. Mines and Geology drilling progress rept. (unpublished).
 4/ Northern Pacific Railway Company.
 5/ A, as received; B, air dried; C, moisture free; D, moisture and ash free.

the Coalwood field (Bryson, 1952), and into the southwestern part of the Mizpah field (Parker and Andrews, 1939). The bed is remarkable for the thickness it maintains throughout these areas.

In a well drilled in 1967, near the Knoblock ranch in sec. 16, T. 5 S., R. 43 E., the bed was logged as 25 feet thick. In a drill hole in sec. 16, T. 4 S., R. 45 E., on Otter Creek, the bed was logged as 47 feet thick. In the Ashland field to the north, it has produced thick clinker and is reported to average 20 feet in thickness in the western part of T. 1 S., R. 44 E. (Bass, 1932, p. 52). In T. 1 S., R. 49 and 50 E., two benches of the Knoblock 45 to 60 feet apart have maximum thicknesses of 13 feet 2 inches (upper) and 7 feet 7 inches (lower) (Bryson, 1952, p. 75). In sec. 23, T. 1 N., R. 49 E., the bed was drilled in 1967 and the upper and lower benches measured 17 feet and 15 feet; they are separated by 3 feet of gray clay. Two cores of the Knoblock bed were obtained during the 1967 field season, one from sec. 36, T. 4 S., R. 45 E., and the other from the Sand Creek deposit in sec. 23, T. 1 N., R. 49 E. The coal at Otter Creek ranks as subbituminous C, whereas the coal at Sand Creek ranks as lignite (Table 3).

The Knoblock has not been mapped in the area west and southwest of Broadus. It may, however, be represented by the thin beds about 80 feet above the Broadus bed near the Superior mine.

Other Mapped Coal beds

Several other coal beds were mapped during the project, but none contained economically important strippable coal deposits in the area included in this report. Some of the beds have sufficient thickness and areal extent to be economically important if favorable topographic conditions can be found in other areas. These coal beds include the Cache, Cook, Ferry, Canyon, and Garfield.

Cache Bed. --The Cache bed was named by Warren (1959, p. 572) for Cache Creek, where it is best exposed. It lies about 350 feet above the Broadus bed and is present on the high buttes and ridges overlooking the Powder River valley. Its northernmost limit was mapped approximately 1 mile northwest of the Black Diamond mine (sec. 11, T. 5 S., R. 50 E.). Warren (1959) reported that in an incomplete section measured in sec. 36, T. 6 S., R. 49 E., the bed is $14\frac{1}{2}$ feet thick and that in many areas the bed occurs in two benches $1\frac{1}{2}$ to 14 feet apart.

The Cache bed as measured on a high sharp ridge near the Superior mine (sec. 14, T. 5 S., R. 50 E.), has a thickness of 8 feet 5 inches and contains a 3-inch carbonaceous shale parting near the center. Two miles farther west, in sec. 16, T. 5 S., R. 50 E., the bed thins to 4 feet 4 inches; it maintains approximately this thickness into sec. 16, T. 5 S., R. 49 E.

The cache bed is readily identified in the field by an associated fossil zone as much as 50 feet thick that lies above the coal bed. Good specimens of various gastropods and pelecypods were collected and sent to the U.S. Geological Survey Paleontology and Stratigraphy Division for identification (App. 2).

Cook Bed. --The Cook bed clinker is exposed near the top of high buttes and ridges in the upper reaches of the Cache Creek and northward to the Sonnette area. Warren (1959) mapped the bed along the Tongue River and stated that the bed reaches a maximum thickness of 25 feet in sec. 36, T. 6 S., R. 48 E. It has also been mapped southward into T. 9 S., R. 47 E. (Bryson and Bass, 1966).

In sec. 16, T. 5 S., R. 48 E., the bed consists of two benches stratigraphically 90 feet apart. Measured thickness of the lower bench is 7 feet 7 inches. The upper bench as measured by Warren (1959) in sec. 21 of the same township has a thickness of 11 feet 5 inches.

Ferry Bed. --The Ferry bed, mapped in sec. 16, T. 4 S., R. 48 E., lies approximately 155 feet above the lower bench of the Cook bed. It has a thickness of 10 feet. Warren (1959, p. 573) reported that the bed has a maximum thickness of 12 feet 6 inches in sec. 6, T. 4 S., R. 47 E.

Canyon Bed. --The Canyon bed crops out along the divide area between the Powder River and Otter Creek drainage. Although no thick coal sections of this bed were measured during this project. Warren (1959, p. 574) reported that it reaches a maximum thickness of about 13 feet in sec. 29, T. 6 S., R. 48 E., and that in T. 5 S., R. 47 and 48 E., it consists of two benches 45 feet to 55 feet apart.

Garfield Bed. --The Garfield coal bed is the highest persistent coal bed in the mapped area. Warren (1959) reported that this bed is extensively burned west of Otter Creek. Along the Pumpkin Creek-Otter Creek divide it occurs in lenticular, bony beds at or near the surface. Because of its proximity to the surface, this coal contains much leonardite and is therefore a possible source of fertilizer.

COAL DEPOSITS

Eight of the eighteen state sections discussed in this report contain strippable coal. In several places strippable coal borders the state sections, and where feasible, the area adjoining the state section was mapped.

Ten of the sections mapped offer little or no potential for strippable coal deposits, but the sections were mapped and described and coal reserves were estimated.

Table 4. --Diagram showing intervals between coal beds by townships.

R. 47 E.	R. 48 E.	R. 49 E.	R. 50 E.
<p>Canyon 200 ft. Cook</p>	<p>Canyon 125 ft. Ferry 155 ft. Cook 170 - 200 ft. Local 75 ft. Pawnee 50 ft. Local</p>		
<p>Garfield 115 - 160 ft. Upper Canyon 60 ft. Lower Canyon 20 - 50 ft. Ferry(?)</p>	<p>Upper Cook 80 ft. Lower Cook 150 ft. Local 85 ft. Pawnee</p>	<p>Local 90 ft. Local 40 ft. Cache 210 ft. Upper Local 110 ft. Lower Local</p>	<p>Pawnee 210 ft. Cache 75 ft. Upper Local 215 ft. Lower Local 100 ft. Broadus</p>
	<p>Garfield 145 - 200 ft. Canyon 110 ft. Local 40 ft. Cook 120 ft. Upper Local 145 ft. Lower Local 70 ft. Pawnee</p>	<p>Cook 170 ft. Upper Local 90 ft. Local 115 ft. Pawnee (?) Local 55 ft. Cache 55 ft. Lower Local</p>	<p>Pawnee 250 ft. Cache 80 ft. Local 270 ft. Broadus</p>

T. 4 S.

T. 5 S.

T. 6 S.

Determination of Coal Thickness

The thickness of the coal in each strippable coal deposit was determined by averaging thicknesses measured during the current investigation, thicknesses in measured sections reported by Warren (1959), and thicknesses determined from drill log data. Logs of water wells on file in the groundwater office of the Montana Bureau of Mines and Geology were reviewed and utilized where applicable. During the investigation, eight holes were drilled in selected locations to determine thickness of coal and of overburden.

The most reliable information as to the thickness of the coal was obtained by the drilling program, which included coring of two coal beds. Measurement of surface exposures was less accurate than drilling, because in most places the base of thick coal beds was not exposed. Logs of water wells are least reliable but were utilized to supplement the information from drilling and from measured sections.

Determination of Overburden

Each area discussed in this report was mapped on aerial photographs. Altimeter surveys were conducted to determine the stratigraphic distance between beds, and to determine the topographic configuration of areas where no topographic maps were available. Outcrop lines of coal beds were drawn on the aerial photograph while in the field.

Preliminary topographic maps on a scale of 1:24,000 were utilized where available, specifically in the Otter Creek and Sonnette areas. In these areas, altitudes of the coal were obtained and plotted on the topographic map. Maps compiled by Warren (1959) were used for reference.

Sufficient altimeter altitudes were obtained in most of the areas to permit fair accuracy in determination of overburden thickness. Before actual mining of any deposit, however, the deposit should be drilled in sufficient detail to permit accurate calculation of the yardage of overburden, as well as the total tonnage of coal.

Estimation of Reserves

Data on the thickness of the coal beds were sufficient to assure a fair amount of accuracy in estimating the coal reserves. The reserve figures are all classed as "indicated reserves" in this report except for the Sonnette area, where reserves are "inferred".

In calculating the reserves of a deposit, the average thickness of the coal was used if more than one measurement was obtained. The area in acres underlain by coal was determined by use of a planimeter to measure the area on the maps made from the air photos. The acreage was multiplied

by the average thickness of the coal to obtain the volume of coal in acre-feet, and this was then multiplied by 1,770 tons to yield the total tonnage. The average weight of 1 acre-foot of Montana subbituminous coal has been determined as 1,770 tons (Averitt and Berryhill, 1950, p. 16).

STRIPPABLE COAL DEPOSITS

The strippable coal deposits are discussed in the order of their importance in terms of total strippable reserves. The Otter Creek deposit, containing reserves estimated at 1,144,000,000 tons, is by far the largest within the report boundaries. The Sonnette deposit, containing 206,000,000 tons, is second. Third is the Pinto Creek-Fire Creek deposit, which is estimated at a minimum of 71,700,000 tons. The Upper Cache Creek deposit is estimated at 39,550,000 tons and the Lower Cache Creek deposit at 10,510,000 tons.

Strippable coal is defined as having less than 150 feet of overburden and a minimum thickness of 6 feet. The coal must be relatively free of partings, and must be sufficiently extensive areally to allow commercial production economically. The strippable coal in the five deposits totals 1,472,000,000 tons.

Otter Creek

The Otter Creek area is in T. 4 and 5 S., R. 45 and 46 E., approximately 12 miles southwest of Ashland by road. Otter Creek, a northward-flowing tributary, joins the Tongue River at Ashland. Except in unusually dry years, it carries water the year around, but it does have periods of no flow. The major tributaries of Otter Creek flow only during periods of heavy precipitation and during the spring runoff. The principal use of land is for livestock grazing, but grain and hay are raised along the valley. The area is defined on the west by high ridges that form the divide between the Tongue River and Otter Creek drainage and on the east by high clinker-topped ridges.

Otter Creek has deeply entrenched meanders, and the present flood plain is about one-eighth mile wide. Red clinker formed by the burning of the underlying Knoblock coal bed borders the edges of the flood plain, forming almost vertical clinker banks in places. A broad terrace approximately 100 to 150 feet above the present level of Otter Creek has been deeply dissected in places by the tributaries of Otter Creek.

Structure. --The strata in the Otter Creek area exhibit several gentle dips and rises, the most prominent of which is the crest of a low anticline trending eastward across the north side of sec. 26, T. 5 S., R. 45 E., where the Knoblock coal bed is exposed about 30 to 40 feet above stream level (Warren, 1959, p. 566). To the north in sec. 16 the Knoblock crops out

near stream level and to the south in the northwest corner of sec. 35 it dips below stream level.

Although the existing data are inconclusive, owing to the paucity of drill data, the isopach map (Fig. 4) of the Knoblock bed suggests that the anticline, as a structural feature, controlled to some extent the deposition and therefore the thickness of the Knoblock coal bed, as there is definite thinning of the Knoblock south of the anticline. From the drill data from the 1967 drilling program, from water well logs, and from an oil well log, the thickness of the Knoblock bed has been computed to decrease from about 40 feet on the north side of the anticline to about 20 feet a short distance south of the anticline.

Coal Beds. --The strata in the Otter Creek area are in the Tongue River Member of the Fort Union Formation. The most important coal bed in the area is the Knoblock bed, which crops out near stream level. The next higher bed is the King bed, which lies 65 to 90 feet above the Knoblock bed in T. 5 S., R. 45 E. (Warren, 1959, p. 569). Other coal beds on the higher slopes of the ridges bordering Otter Creek are the Odell bed, Wall bed, Canyon bed, Dunning bed, Garfield bed, and Cook bed. None of these beds were mapped on this project.

Knoblock Bed. --The Knoblock bed was cored in sec. 36, T. 4 S., R. 45 E., and the analysis shows that it is subbituminous C having a Btu value of 8,740 (Table 3). The Knoblock underlies most of the area except where it has been eroded by Otter Creek. Its base is exposed near stream level in the north-central part of T. 4 S., R. 45 E., and southward into T. 5 S., R. 45 E., as far as sec. 26. The bed has burned where exposed at stream level, and its clinker covers broad areas along the Otter Creek drainage.

King Bed. --Locally, the King bed forms a good marker bed for determining the thickness of overburden over the underlying Knoblock coal bed. It is $1\frac{1}{2}$ feet thick where measured by Warren (1959) in the southwest corner of sec. 24, T. 5 S., R. 45 E. The bed was measured at several places in T. 4 S., R. 45 E., and there its thickness ranges from 2 feet 1 inch to 4 feet 6 inches.

Strippable Reserves for Otter Creek. --The indicated strippable reserves for Otter Creek were based upon the isopach map of the area (Fig. 4) and the overburden map (Pl. 1). Thickness of the coal ranges from 20 feet in T. 5 S., R. 45 E., to 40 feet or more in T. 4 S., R. 45 E.

The overburden map was compiled on a U.S. Geological Survey topographic map on a scale of 1:24,000 with the aid of the report by Warren (1959). A maximum thickness of 150 feet of overburden was used as the limit. The isopach map was compiled from data collected during the drilling program and from water-well logs on file with the Ground Water Branch of the Montana Bureau of Mines and Geology (Table 5).

In the Otter Creek area the indicated strippable coal reserves under 150 feet of overburden or less total 1,144,000,000 tons underlying 21,766 acres. The details of coal reserves by township are as follows:

T. 4 S., R. 45 E. --Indicated strippable coal reserves total 618,000,000 tons underlying 9,500 acres. A breakdown by coal thickness is as follows:

40 feet of coal; 7,020 acres containing 497,000,000 tons
30 feet of coal; 2,080 acres containing 107,000,000 tons
20 feet of coal; 400 acres containing 14,000,000 tons

T. 4 S., R. 46 E. --Indicated strippable coal reserves total 61,000,000 tons underlying 1,291 acres. A breakdown is as follows:

40 feet of coal; 434 acres containing 30,800,000 tons
20 feet of coal; 857 acres containing 30,200,000 tons

T. 5 S., R. 45 E. --Indicated strippable coal reserves total 384,400,000 tons underlying 8,700 acres. A breakdown is as follows:

40 feet of coal; 1,610 acres containing 114,000,000 tons
30 feet of coal; 963 acres containing 51,000,000 tons
20 feet of coal; 6,127 acres containing 219,400,000 tons

T. 5 S., R. 46 E. --Indicated strippable coal reserves total 80,600,000 tons underlying 2,275 acres. The coal is less than 30 feet thick throughout this township.

Sec. 16, T. 4 S., R. 45 E. --Sec. 16, T. 4 S., R. 45 E., lies just west of Otter Creek, and the Otter Creek road crosses the eastern half of the section. Clinker formed by the burning of the Knoblock coal bed covers several acres in the eastern part of the section. A hole was drilled in the southeast quarter, and the log showed 47 feet of Knoblock bed (Table 5). The 50-, 100-, and 150-foot overburden lines are shown on the sketch map (Fig. 5).

Strippable Reserves. --Indicated strippable reserves total 34,200,000 tons underlying 411 acres.

0 to 50 feet of overburden, 103 acres containing
8,500,000 tons
50 to 100 feet of overburden, 226 acres containing
18,900,000 tons
100 to 150 feet of overburden, 82 acres containing
6,800,000 tons

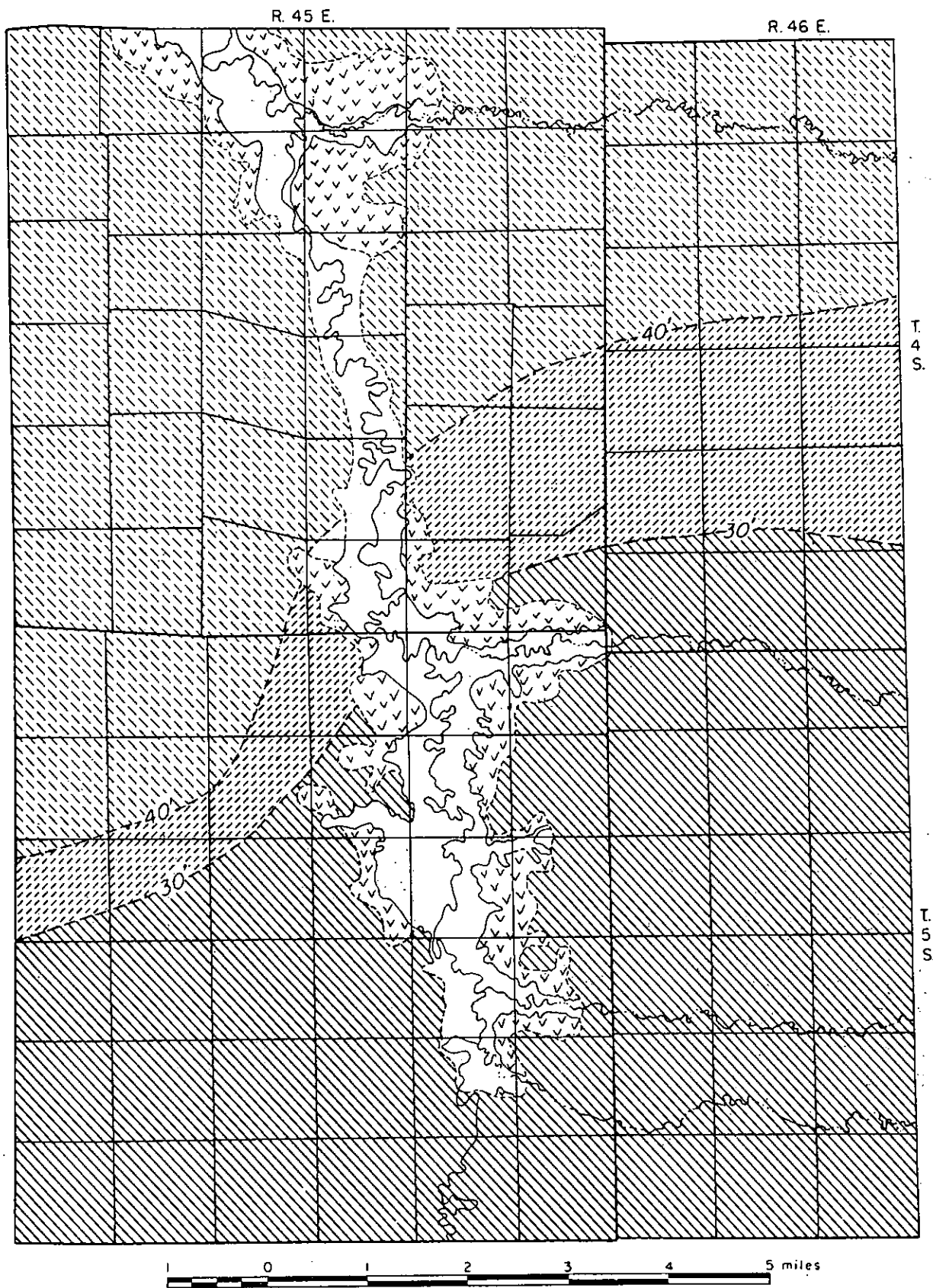


Figure 4. --Isopach map of Knoblock coal bed in the Otter Creek vicinity.

Sec. 36, T. 4 S., R. 45 E. --Sec. 36, T. 4 S., R. 45 E., lies just east of Otter Creek and just north of Tenmile Creek. Tenmile Creek road crosses the southeastern corner of the section. Clinker formed from the burning of the underlying Knoblock bed covers small areas in the southern part of the section (Fig. 6). A hole was drilled in the southeast quarter of the section, and the log showed 21 feet of Knoblock (Table 5). A core sample was extracted 100 feet north of the drilled hole. Analysis of the core shows that the coal is subbituminous C and has a heating value of 8,740 Btu (Table 3).

Strippable Reserves. --The Knoblock bed underlies the entire section, but three fingers of clinker occupy part of the southern edge of the section. The acreage and indicated strippable reserves under a maximum of 150 feet of overburden total 19,500,000 tons, divided as follows:

0 to 50 feet of overburden,	310 acres containing
	11,500,000 tons
50 to 100 feet of overburden,	178 acres containing
	6,300,000 tons
100 to 150 feet of overburden,	39 acres containing
	1,700,000 tons

Scale 1:24,000

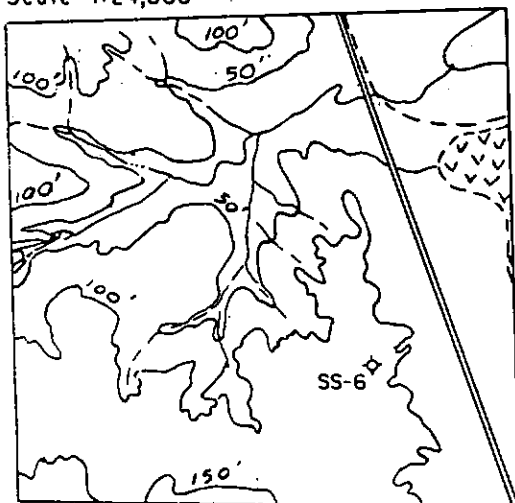


Figure 5. --Sketch map of sec. 16,
T. 4 S., R. 45 E.

Scale 1:24,000

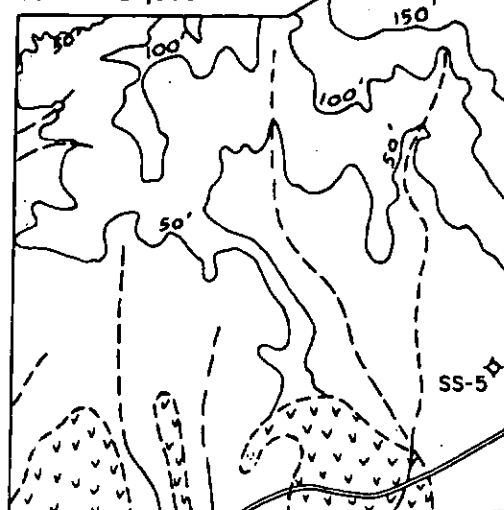


Figure 6. --Sketch map of sec. 36,
T. 4 S., R. 45 E.

Sec. 16, T. 5 S., R. 45 E. --Sec. 16, T. 5 S., R. 45 E., lies west of Otter Creek and is underlain by the Knoblock coal bed. The Knoblock, as logged in drill hole SS-7, has a thickness of 24 feet. The King coal bed crops out along a ridge in the south half and the northwest corner of the section (Fig. 7).

Strippable Reserves. --The strippable coal in this section lies in the northeast quarter where the overburden ranges from near 100 to 150 feet. The inferred strippable coal reserves total 9,500,000 tons underlying 222 acres.

Sec. 36, T. 5 S., R. 45 E. --Sec. 36, T. 5 S., R. 45 E., lies just east of Otter Creek. Topographically, it is one of the most rugged sections in the valley. Although the Knoblock coal bed underlies the entire section, high ridges preclude stripping except in a very small part. The overburden limit line is shown on Figure 8. The Knoblock is 21 feet thick in drill hole SS-8 (Table 5). The King bed crops out along the sides of the high buttes and ridges.

Strippable Reserves. --The ruggedness of this section limits its strippable area to 93 acres under 150 feet of overburden or less. The indicated reserves total 3,500,000 tons.

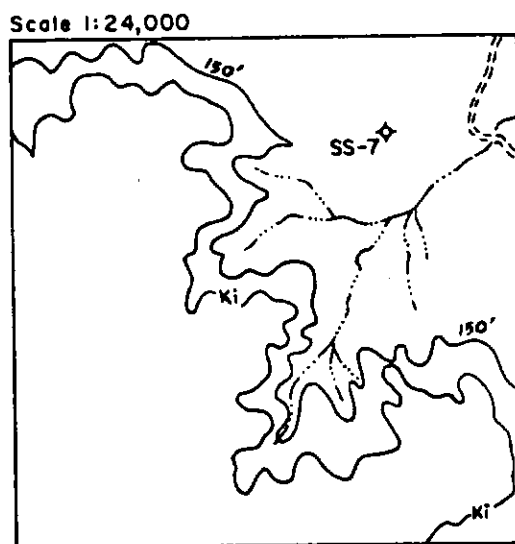


Figure 7. --Sketch map of sec. 16,
T. 5 S., R. 45 E.

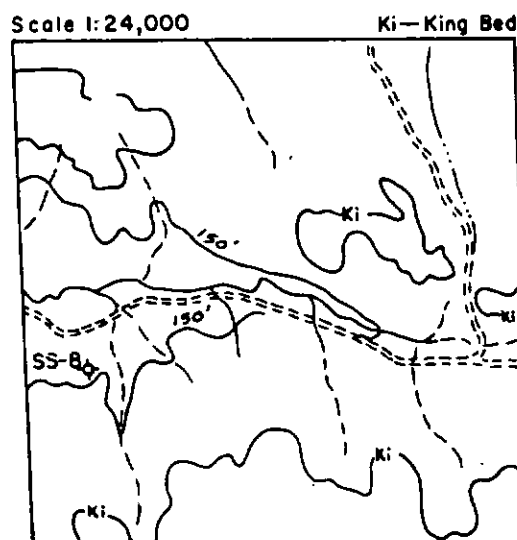


Figure 8. --Sketch map of sec. 36,
T. 5 S., R. 45 E.

Table 5. --Drill-log data for the Otter Creek area.

The following drill-log data were used to compile the isopach map of the Otter Creek area. Part of the information was collected during the drilling program carried out during the summer of 1967, part came from the files of the Ground Water Branch of the Montana Bureau of Mines and Geology, and additional information came from an oil well log.

The following logs were made by the Mineral Fuels Branch of the Montana Bureau of Mines and Geology during the 1967 summer investigation of the area:

Hole SS-5			Hole SS-6		
Collar elevation: 3,264 ft.			Collar elevation: 3,160 ft.		
Total depth: 150 ft.			Total depth: 180 ft.		
Location: 1,615 ft. N. and 150 ft. W. of the SE cor. sec. 36, T. 4 S., R. 45 E.			Location: SW $\frac{1}{2}$ SE $\frac{1}{4}$ sec. 16, T. 4 S., R. 45 E.		
<u>From</u>	<u>To</u>	<u>Lithology</u>	<u>From</u>	<u>To</u>	<u>Lithology</u>
0	17	yellow clay	0	5	yellow sand
17	34	gray clay	5	12	gray and yellow clay
34	37	coal	12	33	gray clay
37	56	gray clay	33	35	yellow limestone concretion layer
56	77	hard coal	35	120	yellow clay
77	114	gray clay	120	167	hard coal
114	120	hard coal	167	168	gray clay
120	123	gray sandy clay	168	169	hard coal
123	127	hard coal	169	180	hard sandy clay
127	150	gray clay			
Hole SS-7			Hole SS-8		
Collar elevation: 3,288 ft.			Collar elevation: 3,259 ft.		
Total depth: 170 ft.			Total depth: 170 ft.		
Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 16, T. 5 S., R. 45 E.			Location: SW $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, T. 5 S., R. 45 E.		

0	5	sand
5	17	yellow clay
17	18	trace coal
18	26	yellow clay
26	47	gray clay
47	50	sandstone
50	62	gray sandy clay
62	80	brown clay
80	98	gray clay
98	102	hard coal
102	113	gray clay
113	137	hard coal
137	148	hard gray sandy clay
148	154	hard coal
154	170	gray sandy clay

0	17	brown clay
17	19	soft coal
19	37	yellow brown clay
37	46	gray clay
46	48	hard coal
48	65	gray clay
65	106	gray sandy clay
106	143	gray clay
143	164	hard coal
164	170	hard gray clay

The following logs were compiled by the Ground Water Branch, Montana Bureau of Mines and Geology:

Total depth: 370 ft.

Location: W $\frac{1}{2}$ SE $\frac{1}{4}$ sec. 18, T. 4 S., R. 45 E.

0	6	subsoil
6	18	clay
18	46	sandstone
46	293	gray shale
293	328	coal
328	370	water sand

Total depth: 325 ft.

Location: NE $\frac{1}{4}$ sec. 19, T. 4 S., R. 45 E.

0	9	surface sand
9	13	hard rock
13	88	blue shale
88	96	coal
96	112	blue shale
112	153	sandstone
153	170	gray shale
170	235	hard sandstone
235	255	gray shale
255	270	water sand
270	320	coal
320	325	gray shale

Table 5. --Drill-log data for the Otter Creek area, contd. --

The following logs were compiled by the Ground Water Branch, Montana Bureau of Mines and Geology:

Total depth: 360 ft.

Location: NE $\frac{1}{4}$ sec. 27, T. 4 S., R. 45 E.

<u>From</u>	<u>To</u>	<u>Lithology</u>
0	30	surface soil
30	68	gravel
68	82	hard rock
82	98	blue clay
98	109	coal*
109	251	gray shale
251	264	sand
264	300	gray shale
300	328	sand
328	336	gray shale
336	350	sand
350	360	gray shale

*Knoblock bed is eroded.

Total depth: 390 ft.

Location: Sec. 25, T. 5 S., R. 45 E.

0	17	sandy clay
17	38	muddy sand
38	46	sand and gravel
46	53	hard sandstone
53	78	clay
78	107	coal
107	149	gray shale
149	164	shale and limestone
164	180	shale
180	207	sand and water

Total depth: 270 ft.

Location: SE $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 5 S., R. 45 E.

<u>From</u>	<u>To</u>	<u>Lithology</u>
0	3	surface soil
3	7	hard rock
7	25	sandstone
25	40	blue shale
40	55	coal
55	162	gray shale
162	170	coal
170	184	gray shale
184	237	coal
237	270	water sand

Total depth: 252 ft.

Location: SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27, T. 5 S., R. 45 E.

0	6	surface soil
6	45	blue shale
45	47	hard rock
47	98	blue shale
98	102	hard rock
102	119	blue shale
119	143	coal
143	211	gray shale
211	250	sandstone
250	252	gray shale

gray shale

252

250

sand and water

207

180

207 254 shale
254 262 coal
262 386 sand
386 390 coal

Total depth: 250 feet
Location: NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 28, T. 5 S., R. 45 E.

0 28 surface soil
28 65 blue shale
65 95 sandstone
95 106 gray shale
106 174 sandstone
174 190 coal
190 211 gray shale
211 241 sandstone
241 250 coal

The following log is the top 240 feet of a lithological log of an oil well:

Collar elevation: 3,178 ft.
Location: Center NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 28, T. 4 S., R. 45 E.

0 90 no sample
90 115 sandstone
115 162 coal
162 210 gray shale
210 240 trace coal, shale

Sonnette

A relatively large deposit of strippable coal of the Pawnee bed is along the upper reaches of Pumpkin Creek near Sonnette. A strippable deposit in the valley extends south from sec. 33 and 34, T. 4 S., R. 48 E., to sec. 8 and 16, T. 5 S., R. 48 E. Narrow bench deposits extend northwest for several miles along each side of Pumpkin Creek, as far as sec. 18, T. 4 S., R. 48 E. (Pl. 2).

The area is easily accessible from east-west U.S. Highway 212 by the Sonnette road. Along Pumpkin Creek, grains and hay are cultivated, but grazing is the principal land use along the valley sides.

Coal Beds. --Of several coal beds in the area, only the Pawnee provides the potentially good strippable coal. The Cook bed is exposed along the ridge tops bordering Pumpkin Creek, but it has been burned over much of the area in the vicinity of sec. 16, T. 5 S., R. 48 E. The Ferry bed and the Canyon bed, both occurring above the Cook bed, are present in the general area.

Pawnee Bed. --The Pawnee coal bed crops out along the sides of Pumpkin Creek valley throughout the western half of T. 4 S., R. 48 E., and passes beneath alluvium in sec. 33. It is presumed to underlie alluvium in sec. 3, 4, 8, and 9, T. 5 S., R. 48 E. In a hole drilled near the north center of sec. 16, a thickness of 22 feet was logged. A core was obtained 4 miles southeast; the analysis shows that it is lignite and has a heating value, on an "as received" basis, of 7,640 Btu.

The drilling log for the hole in sec. 16, T. 5 S., R. 48 E., is as follows:

Drill hole SS-4
Collar elevation 3,807 feet
Total depth 200 feet

From (ft.)	To (ft.)	Description
Top		Alluvium
0	14	Brown sand
14	15	Sandstone
15	32	Yellow clay
32	65	Gray clay
65	70	Gray clay and traces of coal
70	98	Gray clay
98	144	Sandy gray clay
144	177	Gray clay
177	199	Coal--Pawnee bed
199	200	Gray clay

A slight anticlinal flexure trends east-northeast (Pl. 2). Its axis lies approximately a mile north of the southern boundary of T. 4 S., R. 48 E. This structure may be the eastward extension of a similar structure on Otter Creek 10 miles to the west.

North of the mapped area, the bed thins and splits into several thin sheets of coal and carbonaceous shale, which Warren (1959) mapped as a local bed. The complex is 16 to 20 feet thick in sec. 5, T. 4 S., R. 48 E.

Cook Bed. --In sec. 16, T. 5 S., R. 48 E., the Cook bed consists of two benches 90 feet apart. Warren (1959, p. 573) reported that in T. 4 and 5 S., R. 47 and 48 E., the Cook bed is split into two benches 40 to 75 feet apart. A resistant well-indurated sandstone bed more than 4 feet thick lies 50 feet above the top of the lower bench, which has a thickness of 7 feet 7 inches in the south center of sec. 16. The upper bench has burned over most of sec. 16, but where measured by Warren (1959) at a mine in the NE $\frac{1}{4}$ sec. 21, its thickness exceeds 11 feet 5 inches. The log of a water well drilled in the SW $\frac{1}{4}$ NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 20 shows 15 feet of coal at a depth of 58 feet and 19+ feet of sandstone at a depth of 91 feet. The coal bed is presumed to be the upper bench of the Cook, as the sandstone correlates with the sandstone between the two benches of the Cook, which is easily recognizable throughout sec. 16.

Strippable Coal. --The Pawnee coal bed is judged to be strippable in the north half of T. 5 S., R. 48 E., and along Pumpkin Creek and its tributaries in T. 4 S., R. 48 E. (Pl. 2).

Inferred reserves were calculated as 206,000,000 tons. The coal was assumed to be 22 feet thick throughout the area, and a maximum overburden thickness of 150 feet was the limit.

Total strippable acreage was calculated as 5,288 acres, broken down as follows:

0 to 50 feet of overburden, 1,383 acres
50 to 100 feet of overburden, 1,666 acres
100 to 150 feet of overburden, 2,239 acres

The inferred strippable tonnage was calculated to be 206,000,000 tons, broken down as follows:

0 to 50 feet of overburden, 53,900,000 tons
50 to 100 feet of overburden, 64,900,000 tons
100 to 150 feet of overburden, 87,200,000 tons

The area is well suited for bench strip mining and has good access to U.S. Highway 212.

Pinto Creek-Fire Creek

Sec. 36, T. 6 S., R. 48 E., lies near the head of Pinto Creek in an area of high buttes and narrow valleys. The section is thinly forested with pine and has good grass cover. The land is used for grazing (Fig. 9).

The maximum relief is approximately 360 feet; altitudes ranging from approximately 3,640 feet in the southeast corner of the section to approximately 4,000 feet in the northwest corner.

Coal Beds. --Two major and several local coal beds are exposed in this general area. The Cook bed is the highest and is burned extensively through the section. Two local beds are exposed 100 to 300 feet below the Cook. The Pawnee coal bed is exposed approximately 360 feet below the Cook clinker (Fig. 9).

Cook Bed. --In this area the Cook is a single bed. The coal is burnt throughout most of the area, and clinker caps the higher buttes and ridges. A thickness of 22 feet was measured by Warren (1959) on the north border of sec. 36, T. 6 S., R. 48 E.

Local Bed. --Two local beds are exposed in the Pinto Creek drainage. The higher bed is 120 feet below the Cook bed, and the lower is 250 to 300 feet below the Cook bed. The upper bed is principally carbonaceous shale grading laterally to previtrain lenses. The lower bed, too, is mainly carbonaceous shale grading to thicker previtrain lenses.

The lower local bed is exposed at stream level near the center of sec. 36. This bed carries water, but the water contains so much dissolved salts that it is used chiefly for stock water.

Pawnee Bed. --The Pawnee bed is exposed along Pinto Creek and Fire Creek (Fig. 9). This bed is potentially strippable throughout the southeast corner of sec. 36 and most of sec. 24 and 25, T. 6 S., R. 48 E.; sec. 19, 29, 30, and 31, T. 6 S., R. 49 E.; sec. 1, T. 7 S., R. 48 E.; and sec. 6, T. 7 S., R. 49 E. Warren (1959) reported this area as potentially strippable. Sec. 24 and 25, T. 6 S., R. 48 E., and sec. 19, 29, and 30, T. 6 S., R. 49 E., were not mapped, owing to lack of aerial photo coverage.

The log of a water well in sec. 8, T. 7 S., R. 49 E., reported 24 feet of coal under approximately 50 feet of overburden. The log reads as follows:

From (ft.)	To (ft.)	Description
0	15	Surface soil
15	25	Sand and gravel
25	35	Red shale
35	50	Clay
50	51	Sandstone
51	75	Coal
75	90	Sandstone
90	100	Blue clay

An incomplete section in the southeast corner of sec. 36 indicated 16 feet 4 inches of coal.

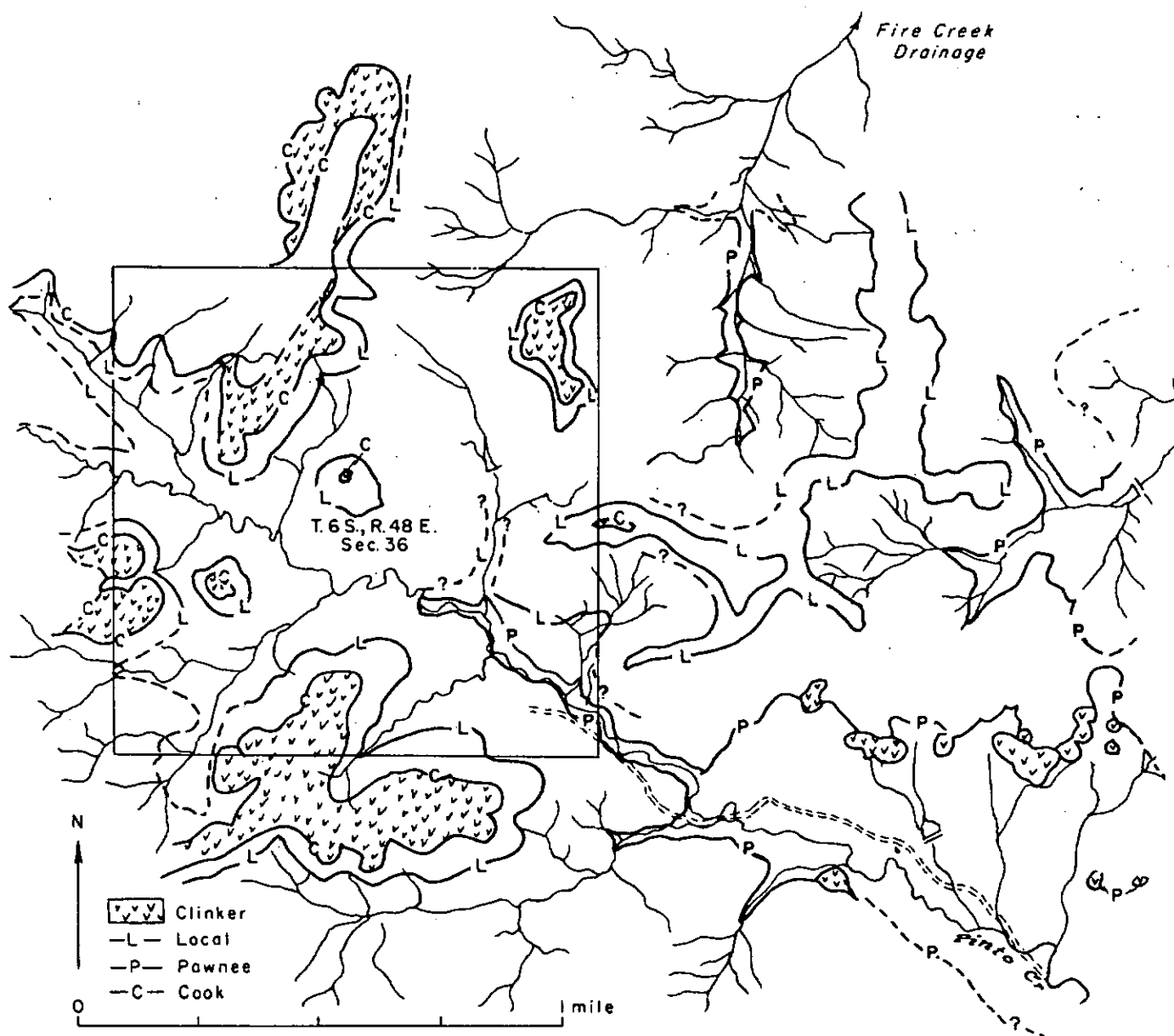


Figure 9. --Sketch map of Pinto Creek-Fire Creek area.

Reserve Estimates. -- These estimates of reserves include only the reserves indicated on Figure 9. The only potentially strippable coal is the Pawnee bed, thickness of which was assumed to be 20 feet. The Pawnee underlies approximately 2,210 acres, and total reserves are estimated at 71,700,000 tons.

Upper Cache Creek

A valley bench of strippable coal extends from sec. 36, T. 5 S., R. 48 E., through part of sec. 31, T. 5 S., R. 49 E., and parts of sec. 4, 5, 8, and 9, T. 6 S., R. 49 E. The strippable coal is the Pawnee bed, which here ranges in thickness from 16 feet 3 inches to 20 feet.

The deposit borders the main drainage of Cache Creek and is limited by high, steep ridges. The topography in the area is rugged, and the relief exceeds 400 feet. Altitudes range from 3,557 feet where the drive-way to the ranch in sec. 4 leaves the access road along Cache Creek to approximately 4,000 feet on the top of the clinker-covered buttes in sec. 36. A thick unit of massive indurated sandstone forms steep escarpments along the buttes and ridges. The land is used for grazing, except for small dry-land farming fields on the valley slopes north of Cache Creek in the north half of sec. 4, T. 6 S., R. 49 E.

Coal Beds. -- The three major coal beds in the area are the Pawnee below, a local bed, and the Cook bed at the top (Pl. 3). A thin local bed about 115 feet above the main local bed was not mapped. Only the Pawnee and the lower local bed have potential for recovery. The lower local bed is 40 to 70 feet above the Pawnee, and the Cook bed is about 350 feet above the Pawnee (measured stratigraphic section, App. 1).

Pawnee Bed. -- Where the Pawnee bed was drilled and cored in the southwest corner of sec. 36, T. 5 S., R. 48 E., its thickness is 20 feet. On the south side of Cache Creek, in sec. 5, T. 6 S., R. 48 E., the bed was almost 15 feet thick and the section is incomplete. About 2 miles southeast, at the Monroe mine, in the north center of sec. 15, T. 6 S., R. 49 E., the bed is 21 feet thick. Analysis of the core shows that coal in the Pawnee bed ranks as lignite and has a heating value of 7,650 Btu on an "as received" basis (Table 3). The drill hole data in this section follow:

Drill hole SS-3
 Collar elevation 3,723 feet
 Total depth 170 feet

From (ft.)	To (ft.)	Description
0	16	Brown clay
16	19	Soft coal
19	21	Gray clay
21	24	Hard coal)
24	26	Gray clay) - Local bed above
26	28	Hard coal) the Pawnee
28	32	Gray clay
32	54	Yellow clay
54	69	Gray clay
69	89	Coal, hard--Pawnee bed
89	127	Gray clay
127	143	Hard gray sand
143	149	Gray clay
149	150	Coal
150	158	Gray clay
158	161	Coal
161	164	Gray clay
164	167	Hard sandstone
167	170	Gray clay

Local Bed. --The lower local bed in this area is about 40 to 70 feet above the top of the Pawnee, and in this vicinity it serves as a good marker bed for stripping limits. It is extensive, for it correlates with the local bed above the Pawnee described under "Sec. 16, T. 6 S., R. 49 E.", where it attains a thickness of at least 15 feet of good coal. In the drill hole in the southwest corner of sec. 36, T. 5 S., R. 48 E., the lower local bed consists of three benches. Where the bed was measured in a cut bank in the center of sec. 36, it consists of a total of 4 feet 3 inches of coal split near the base by a parting 1 foot 3 inches thick. A measured section follows:

Feet	Inches	Description
Top		Covered
3	4	Shale, brown, moderately fissile; abundant gypsum
4	6	Carbonaceous shale, light gray, fissile
1	4	Shale, light gray, moderately fissile
0	6	Carbonaceous shale, dark gray, fissile
3	1	Coal, weathered; abundant woody previtrain
1	3	Clay, dark brown
2	0	Coal; abundant woody previtrain
Base		Claystone, yellowish gray to dark yellowish gray

Cook Bed. --The Cook bed has burned over the entire area, and its clinker caps the steep-sided buttes and ridges.

Strippable Reserves. --Although the terrain is generally rugged, an area of 1,280 acres is suitable for strip mining. A breakdown of acreage-overburden is as follows:

0 to 50 feet of overburden, 517 acres
50 to 100 feet of overburden, 483 acres
100 to 150 feet of overburden, 286 acres

The thickness of the Pawnee ranges from 16 feet 3 inches to 20 feet, and reserves are estimated to total 39,550,000 tons. A breakdown of tonnage-overburden is as follows:

0 to 50 feet of overburden, 17,630,000 tons
50 to 100 feet of overburden, 14,387,000 tons
100 to 150 feet of overburden, 7,530,000 tons

The local bed above the Pawnee is also strippable throughout most of same areas. As the bed differs so greatly in thickness from place to place, reserves were not estimated.

Lower Cache Creek

The Lower Cache Creek deposit underlies the north half of sec. 36 and parts of sec. 25, 26, and 35, T. 5 S., R. 49 E., and part of sec. 31, T. 5 S., R. 50 E. (Pl. 4).

This area lies in the main drainage of Cache Creek, which has formed a valley one-half to one mile wide. Cache Creek is an intermittent stream and a major tributary of the Powder River. The land is used for grazing. The altitude in sec. 36 ranges from 3,248 feet on the main drainage of Cache Creek in the northeast corner of the section to 3,725 feet in the southwest corner. The south half of sec. 36 is deeply dissected by gullies lying between buttes and ridges capped by massive sandstone. The higher buttes in the southwest corner of the section are capped with clinker from burning of the Pawnee coal bed.

Coal Beds. --Of the three major coal beds exposed in this area, only the Broadus bed has potentially strippable coal. Other beds present in the area are the Cache, the Pawnee, and two thin local beds lying between the Broadus bed and the Cache bed.

Broadus Bed. --The Broadus coal bed underlies the entire area. In a drill hole in sec. 36, T. 5 S., R. 49 E. (Pl. 4), the Broadus bed was logged as 12 feet thick; the log is as follows:

Drill hole SS-2
 Collar elevation 3,317 feet
 Depth 150 feet

From (ft.)	To (ft.)	Description
0	18	Yellow sand
18	21	Gray clay
21	23	Coal, weathered
23	28	Gray clay
28	39	Yellow sandy clay
39	54	Gray and yellow clay
54	56	Hard coal
56	85	Gray clay
85	86	Gray water-bearing sand
86	99	Gray sandy clay
99	100	Trace of coal
100	103	Gray clay
103	105	Coal, hard
105	128	Gray sandy clay
128	140	Hard coal -- Broadus bed
140	150	Gray clay

Cache Bed. --Where the Cache bed crops out in the southwest corner of sec. 36, a thickness of 5 feet was measured. Carbonaceous shale lies below and above the coal. The Cache bed has burned over much of the area, and its clinker is exposed on isolated knolls.

Pawnee Bed. --Clinker formed by the burning of the Pawnee bed caps two high buttes in the southwest corner of the section.

Local Beds. --There are two thin local beds between the Broadus bed and the Cache Bed. The lower bed is about 150 feet above the Broadus bed and consists of carbonaceous shale grading laterally into 6 inches of coal. The other local bed is 4 feet thick and consists principally of previtrain. It is about 175 feet above the top of the Broadus bed. Three other thin local beds were logged in the drill hole.

Strippable Reserves. --The Broadus bed, averaging 12 feet thick, is the only coal bed that is potentially strippable. Estimated strippable reserves total 10,510,000 tons. A breakdown of the tonnage-overburden limit is as follows:

50 to 100 feet of overburden, 2,030,000 tons
 100 to 150 feet of overburden, 8,480,000 tons

The strippable coal underlies an area of approximately 490 acres along the valley walls. A breakdown of acreage-overburden limit is as follows:

50 to 100 feet of overburden, 95 acres
100 to 150 feet of overburden, 395 acres

COAL IN OTHER STATE SECTIONS

Reserves totaling 70,920,000 tons of coal are delineated for the following sections. Although these deposits are currently judged to be noncommercial, we do not rule out the possibility that they may become valuable as mining techniques improve and as hydrocarbons become more valuable.

Sec. 36, T. 4 S., R. 47 E.

Sec. 36, T. 4 S., R. 47 E., is west of Pumpkin Creek and is accessible by the Tenmile Creek road and a Forest Service trail west of Sonnette. The section is deeply dissected by two northward-trending drainages and is utilized exclusively for grazing. Except in the northeast quarter, exposures are poor, owing to heavy foliage and grass cover. The section has no potential for strippable coal.

Coal Beds. --Two coal beds are exposed in the section, the Cook and the Canyon bed. They are about 200 feet apart (Fig. 10).

Cook Bed. --The Cook bed crops out in the north-central part of the section and has been burned over most of its outcrop area. A thickness of 1 foot 4 inches was measured in one locality.

Canyon Bed. --No outcrops of the Canyon bed were seen, but altitudes were obtained from coal "bloom" areas in the southwest quarter and at the base of its clinker in the southeast quarter of the section.

Coal Reserves. --Because of the paucity of data, no reserve calculations were made for this section.

Sec. 16, T. 4 S., R. 48 E.

Sec. 16, T. 4 S., R. 48 E., is on the east side of the divide between Pumpkin Creek and Mizpah Creek, in an area used exclusively for grazing. The section is deeply dissected, and local relief exceeds 450 feet. Because of the ruggedness of the terrain, there is scant possibility of strip mining.

Coal Beds. --The coal beds exposed in the section include a local bed above the Pawnee, the Cook bed in two benches, the Ferry bed, and the Canyon

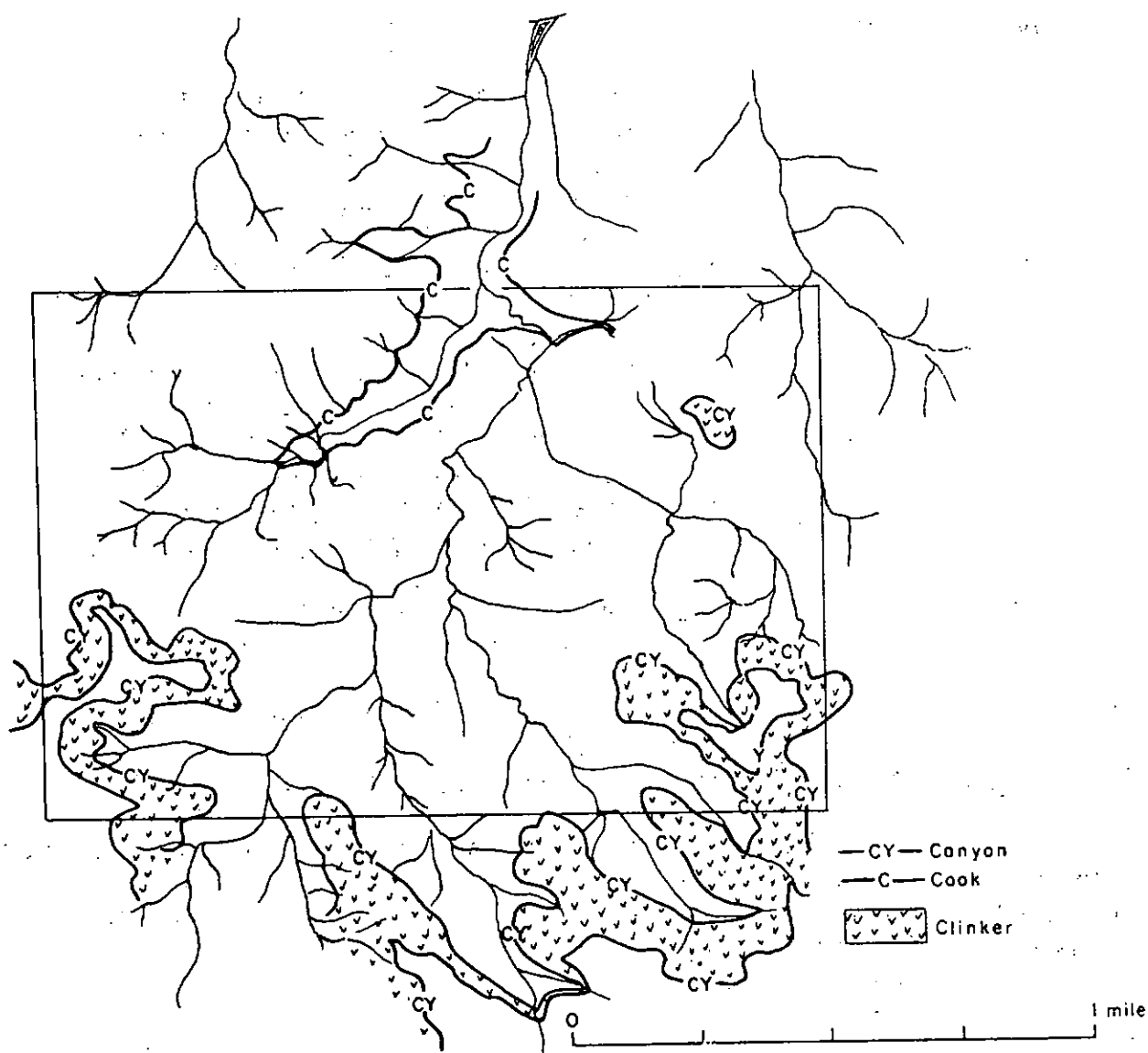


Figure 10. --Sketch map of sec. 36, T. 4 S., R. 47 E.

bed (Fig. 11). The lower bench of the Cook bed is 170 to 200 feet above the local bed, the Ferry bed is 155 feet above the Cook bed, and the Canyon bed is about 120 feet above the Ferry bed.

Local Bed. --A local bed crops out in a cut bank near the southwest corner of the section. A thickness of 7 feet 11 inches was measured, but the base was not exposed. A measured section of the coal and the beds above the coal follows:

Feet	Inches	Description
8+	0	Claystone, light yellowish gray to light yellowish orange; contains ironstone
1	0	Carbonaceous shale, light brown to gray; scattered carbonized plant fragments
1	2	Coal, abundant woody previtrain
0	4	Carbonaceous shale, dark gray to black, cleated
0	3	Coal, weathered
0	2	Underclay, purplish gray to dark gray, non-fissile; carbonized plant fragments
5	8	Sandstone, pale olive, very fine grained; contains siderite concretions
11	10	Claystone, light yellowish gray to light yellowish orange; pelecypod fragments, siderite concretions
0	1	Claystone, dark olive gray to light brown
7	11	Coal, weathered, large woody previtrain

A higher local bed 3 feet 5 inches thick was measured and mapped by Warren (1959) in a small area in the southwest quarter of the section. This bed was not found during the current mapping program.

Cook Bed. --The Cook bed consists of two benches. In the southwest quarter of the section, the benches are 2 feet apart. The lower bench was not measured, as it had burned at its outcrop, but the upper bench measured a maximum of 5 feet 8 inches in thickness. Both benches have burned over much of the area where they crop out.

Ferry Bed. --The Ferry bed is exposed in the north half of the section on the sides of steep clinker-capped ridges. The bed has burned over much of the area and has formed thick clinker. A total thickness of 10 feet was measured near the center of the section, as follows:

Feet	Inches	Description
Top		Sandstone, light yellowish gray to light yellowish orange, fine grained; scattered siderite concretions
1	0	Carbonaceous shale, light olive gray to light brown
4	0	Coal, weathered; abundant selenite
0	8	Carbonaceous shale, dark brown
6	0	Coal, weathered; abundant selenite
Base		Underclay, dark brown; carbonized plant fragments

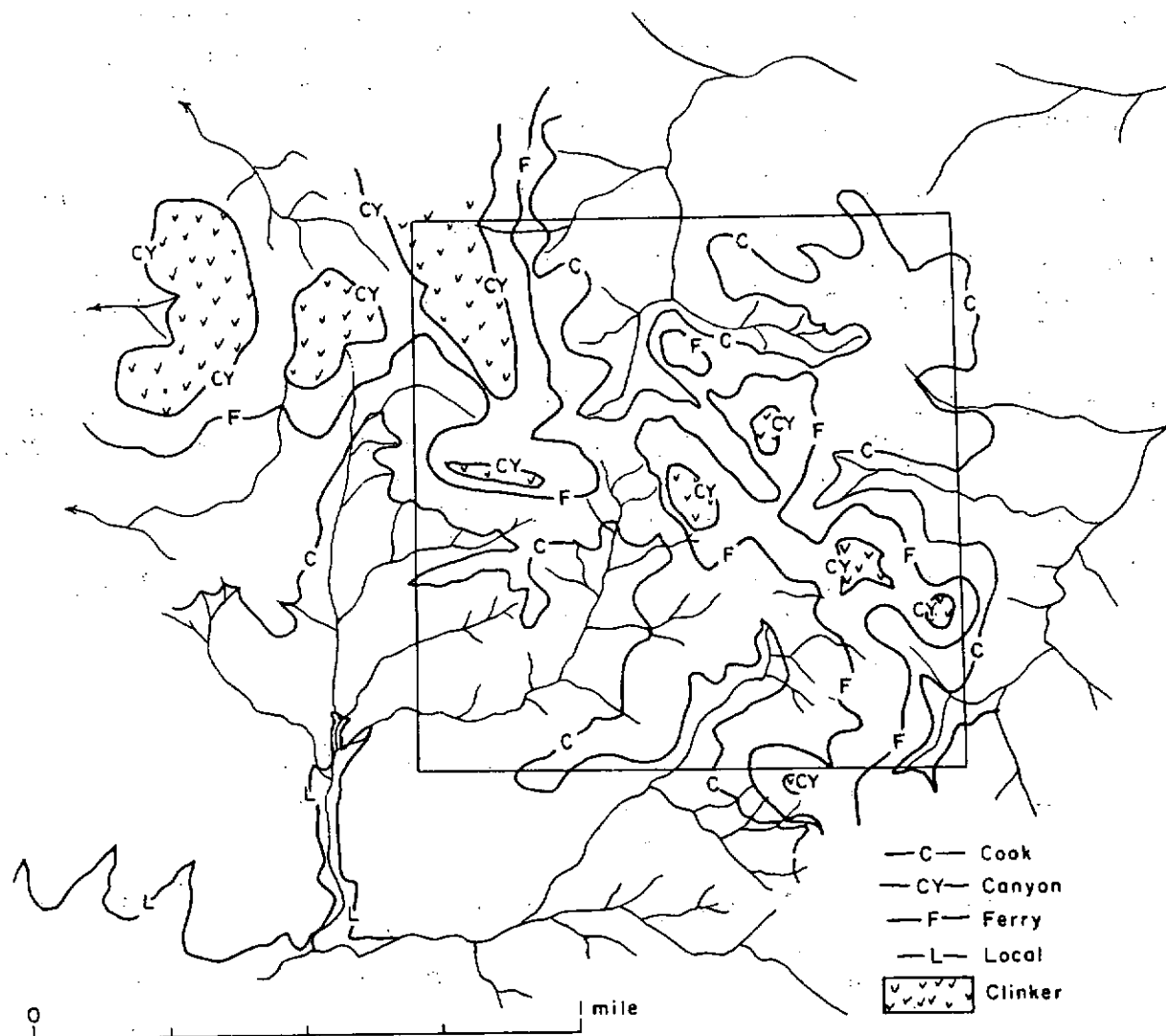


Figure 11. --Sketch map of sec. 16, T. 4 S., R. 48 E.

Canyon Bed. --Clinker formed by burning of the Canyon bed is exposed near the top of the highest ridges in the section.

Reserves. --The major coal reserves are in the upper bench of the Cook bed and in the Ferry bed. The reserves total 6,918,000 tons, of which the Cook bed, which underlies 420 acres, contains 4,210,000 tons and the Ferry bed, which underlies 153 acres, contains 2,708,000 tons.

Sec. 36, T. 4 S., R. 48 E.

Sec. 36, T. 4 S., R. 48 E., is on the east side of the divide between the Mizpah Creek drainage and Pumpkin Creek. The section is deeply dissected and the local relief is about 280 feet between the southeast and southwest corners of the section. The area is utilized exclusively for grazing. There is no potentially strippable coal in this area, owing to the ruggedness of the terrain and the relatively small reserves.

Coal Beds. --The coal beds exposed in the section include a local bed below the Pawnee, the Pawnee bed, a local bed above the Pawnee, and the Cook bed (Fig. 12). The lower local bed is about 50 feet below the Pawnee, and the upper local bed is about 75 feet above the Pawnee. The Cook bed is about 170 feet above the upper local bed.

Pawnee Bed. --Except for its clinker, the Pawnee bed is not exposed in this section; the bed has burned along its outcrop throughout the section. Incomplete sections of the Pawnee measured in sec. 1 and 13, T. 5 S., R. 48 E., by Warren (1959) show 6+ feet and 10+ feet, respectively.

Local Beds. --The local bed below the Pawnee has a thickness of 2 feet where measured near the southeast corner of the section:

Feet	Inches	Description
0	6	Carbonaceous shale, brown
2	0	Coal, large pieces of woody previtrain
0	3	Underclay, dark olive

The upper local bed has a measured thickness of 1 foot 7 inches:

Feet	Inches	Description
10+		Claystone, gray, weathers light yellowish gray to light yellowish orange; abundant ironstone layers
1	7	Coal, weathered, 1-inch clay parting 4 inches below top; some previtrain
0	3	Claystone, dark brown, conchoidal fracture and vitreous luster
0	2	Coal, weathered
0	6	Claystone, brown; contains carbonized plant fragments and plant impressions

Cook Bed. --The Cook bed crops out near the top of a high knoll in the center of the section and in the southwest quarter of the section, where a thickness of 3 feet 5 inches was measured:

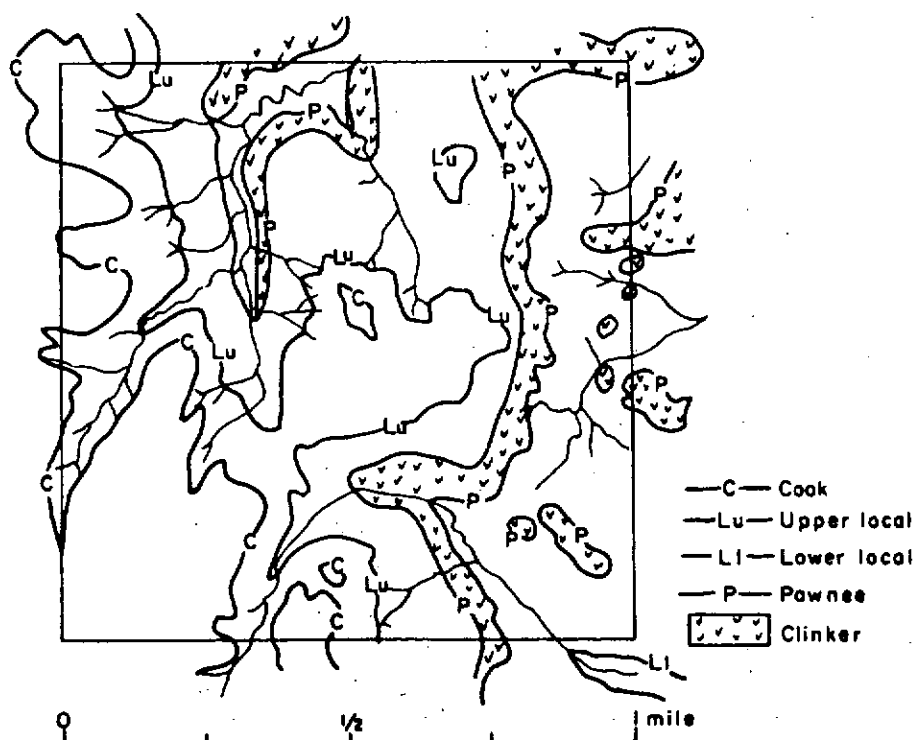


Figure 12. --Sketch map of sec. 36, T. 4 S., R. 48 E.

Feet	Inches	Description
2+	0	Sandstone, fine grained, well sorted, pale olive to light yellowish gray
3	5	Coal, deeply weathered
0	6	Underclay, pure, brown

Reserves. --The coal reserves in this section total 11,594,680 tons, but the lower and upper local beds, which are only 2 feet thick, contain 3,157,680 tons of this total. The Cook bed underlies 100 acres and contains 892,000 tons. The Pawnee bed, where it has not been burned, underlies 425 acres and contains reserves of 7,545,000 tons.

Sec. 36, T. 5 S., R. 47 E.

Sec. 36, T. 5 S., R. 47 E., is at the head of Fifteenmile Creek in an area of narrow ridges and drainages, which trend approximately N. 45° W. The local relief exceeds 250 feet, altitudes ranging from approximately 3,900 feet in the northwest corner of the section to approximately 4,150 feet in the southeast corner. The section lies approximately half a mile west of the Otter Creek-Pumpkin Creek divide.

The land is used principally for grazing, although some dryland farming is practiced on the broader ridge tops of the divide. Stock water is supplied from earthen reservoirs scattered in the area.

Coal Beds. --The Ferry(?), lower and upper Canyon, and Garfield beds all crop out in this area (Fig. 13). The lower Canyon is 50 feet above the Ferry, the upper Canyon (Canyon zone), 20 to 50 feet above the lower Canyon, and the Garfield, 115 to 160 feet above the upper Canyon.

The Canyon zone and the Garfield bed crop out in the narrow ridges and are widely scattered; the Ferry(?) bed crops out in the major drainage.

Ferry(?) Bed. --The Ferry(?) bed crops out in Fifteenmile Creek. A section measured in a meander scar near the center of the section follows:

Feet	Inches	Description
Top		Interbedded carbonaceous shale and dusky-yellow mudstone
2	11	Coal, mainly previtrain, slightly weathered
1	3	Claystone, pale olive, slightly silty
0	6	Carbonaceous shale, light purple
3	4	Coal, mainly previtrain, weathered and slightly altered to leonardite
Base		Carboniferous shale, black to dark brown; numerous plant fragments

Total thickness 8 feet

Total thickness of coal 6 feet 3 inches

The Ferry(?) bed was mapped as lowest Canyon by Warren (1959), but figures from his report would indicate that this is either the Ferry bed or a local coal bed.

Canyon Zone. --The Canyon zone flanks the higher ridges of the section and consists of two coal beds separated by 20 to 50 feet of carbonaceous shale, claystone, and sandstone. A section of the lower bed, measured north of the northwest corner of the section follows:

Feet	Inches	Description
Top		Interbedded dark-olive claystone and yellowish-gray carbonaceous shale
1	8	Coal, mainly previtrain, slightly weathered to leonardite
1	10	Carbonaceous shale grading laterally to coal

Total thickness 3 feet 6 inches
Total thickness of coal 1 foot 8 inches

Garfield Bed. --The Garfield bed crops out on the higher ridges in the area, and is deeply weathered throughout. The only exposures of this bed are near the center of the eastern boundary and in the northeast corner of the section. A section measured in the northeast corner follows:

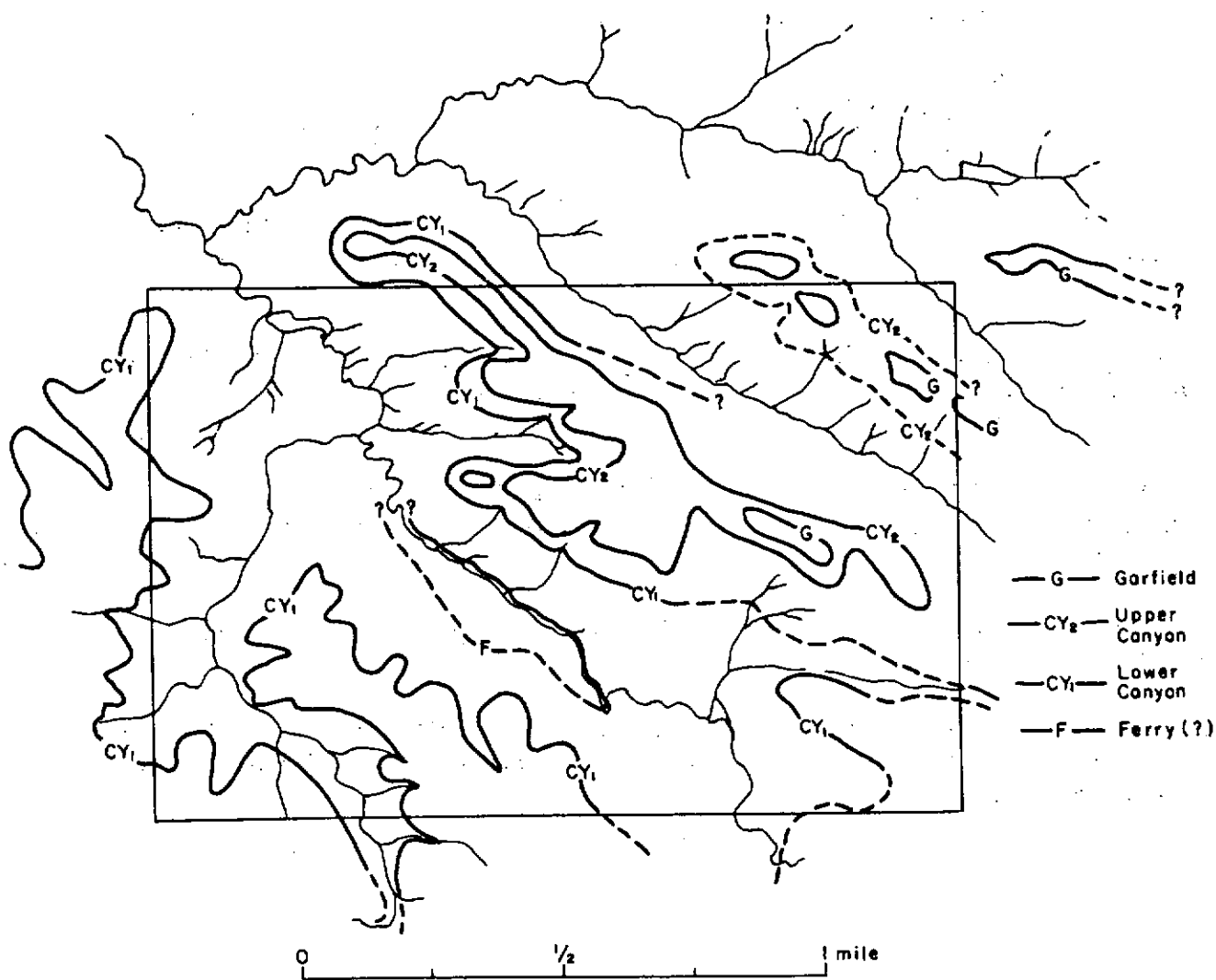


Figure 13. --Sketch map of sec. 36, T. 5 S., R. 47 E.

Feet	Inches	Description
Top		Alluvium
18	3	Interbedded carbonaceous shale and thin coal seams
3	10	Claystone, pale olive to blue gray, slightly silty, interbedded with carbonaceous shale, purplish brown, very fissile
0	4	Carbonaceous shale, purplish brown, very fissile
4	6	Coal, principally previtrain
Base		Underclay, slightly silty, blue gray to pale olive; abundant carbonized plant fragments

Total thickness 26 feet 11 inches

Total thickness of coal 4 feet 6 inches

Reserves. --Reserves in sec. 36, T. 5 S., R. 47 E., exceed 8,050,000 tons, but are currently noncommercial. The coal is contained in three beds that crop out along the principal drainages, as follows:

Ferry(?) bed. --The Ferry(?) bed averages 6 feet 3 inches in thickness and underlies an area of 578 acres. The estimated reserve totals 6,400,000 tons.

Lower Canyon bed. --The lower Canyon bed averages 2 feet in thickness and underlies an area of 351 acres. The estimated reserve totals 1,243,000 tons.

Upper Canyon bed. --The upper Canyon bed averages 2 feet in thickness and underlies an area of 115 acres. The estimated reserve totals 407,000 tons.

Garfield bed. --The small areal extent and the extensive weathering of the coal render this bed noncommercial.

The small areal extent, thinness of the beds, and in some places, the large amount of overburden combine to render the coal in this section noncommercial.

Sec. 16, T. 5 S., R. 49 E.

Sec. 16, T. 5 S., R. 49 E., is on the North Fork of Cache Creek. The terrain is rugged and deeply dissected, making strip mining impractical. In addition, the thickness of the coal is not sufficient to warrant strip mining. The section, which has not been previously mapped, is of interest because of the fossiliferous zone above the Cache coal bed and because of the petrified wood exposed at the top of the stratigraphically highest coal bed.

The fossiliferous sequence above the Cache coal bed was measured in the south-central part of the section, as follows:

Feet	Inches	Description
Top		Sandstone, poorly exposed, yellowish gray; fossil pelecypods bed at base
2	9	Carbonaceous shale, pale brown, fissile
0	7	Coal, weathered; abundant previtrain
8	2	Covered
1	0	Carbonaceous shale, pale brown, fissile
30	4	Claystone, light gray and light yellowish gray to dark yellowish orange, variegated, bentonitic; selenite abundant, abundant gastropods and few pelecypods, ironstone concretion layers throughout
4	7	Carbonaceous shale, grayish brown, fissile; carbonized plant fragments and impressions, gypsum crystals along fissility
12	5	Covered
4	8	Cache coal bed, abundant previtrain
Base		1-inch silty pale-yellowish-brown clay parting 1 foot 4 inches below top of coal

Coal Beds. --The two coal beds of interest in this section include the Cache bed and an upper bed, believed to be the Pawnee(?) bed, which is 200 feet above the Cache bed (Fig. 14).

Cache Bed. --Thickness of the Cache bed measured in the southwest quarter of sec. 16 is 3 feet 9 inches and in the northeast quarter is 4 feet 8 inches. A thin parting occurs about a foot below the top of the bed in both areas.

Pawnee Bed(?). --A coal bed that is believed to be the Pawnee bed is exposed near the top of a narrow, northwest-trending ridge in the west-central part of the section. The bed is 4 feet 4 inches thick, and silicified logs and stumps are abundant near the top of the bed.

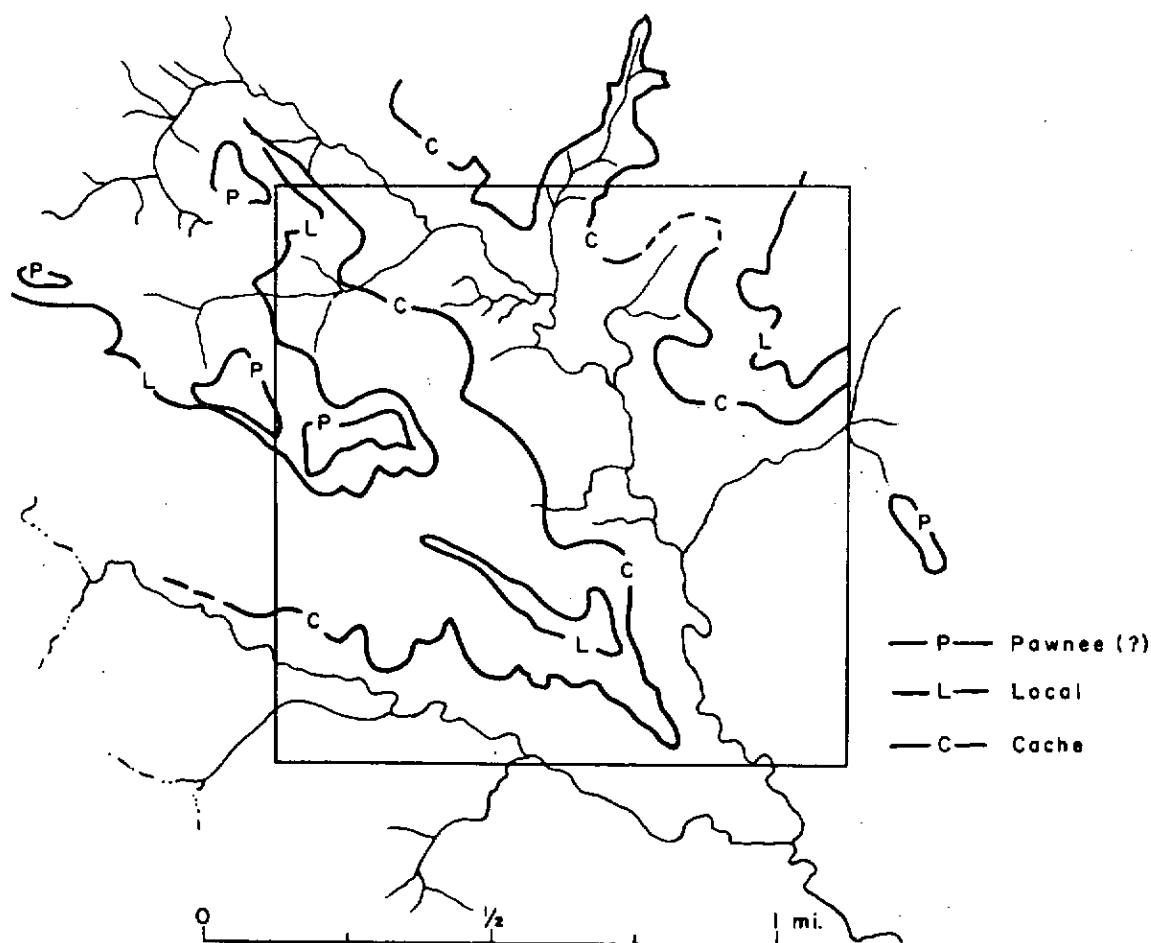


Figure 14. --Sketch map of sec. 16, T. 5 S., R. 49 E.

Reserves. --The estimated reserves of coal in the section total 2,157,860 tons. The Cache bed underlies 286 acres and contains reserves of 2,126,000 tons, the Pawnee(?) bed underlies only $4\frac{1}{2}$ acres and contains reserves of 31,860 tons.

Sec. 16, T. 5 S., R. 50 E.

Sec. 16, T. 5 S., R. 50 E., is about 2 miles northwest of the Powder River valley. Altitudes in the area range from 3,256 feet at the top of the Broadus coal bed, in adjacent sec. 21, to 3,900 feet or higher at the top of the clinkered ridge in the northern part of sec. 16. The area is rugged and deeply dissected.

A small area underlain by the Broadus bed in sec. 21 and 22 is strippable, but because of lack of aerial photo coverage during the field season, it was not mapped. The strippable area would probably be about 200 acres, beginning at the outcrop of the Broadus bed and extending eastward into the center of sec. 22.

Coal Beds. --The five coal beds in sec. 16 are the Broadus bed, two local beds, the Cache bed, and the Pawnee bed (Fig. 15). The Broadus bed crops out in the southeast quarter of sec. 21.

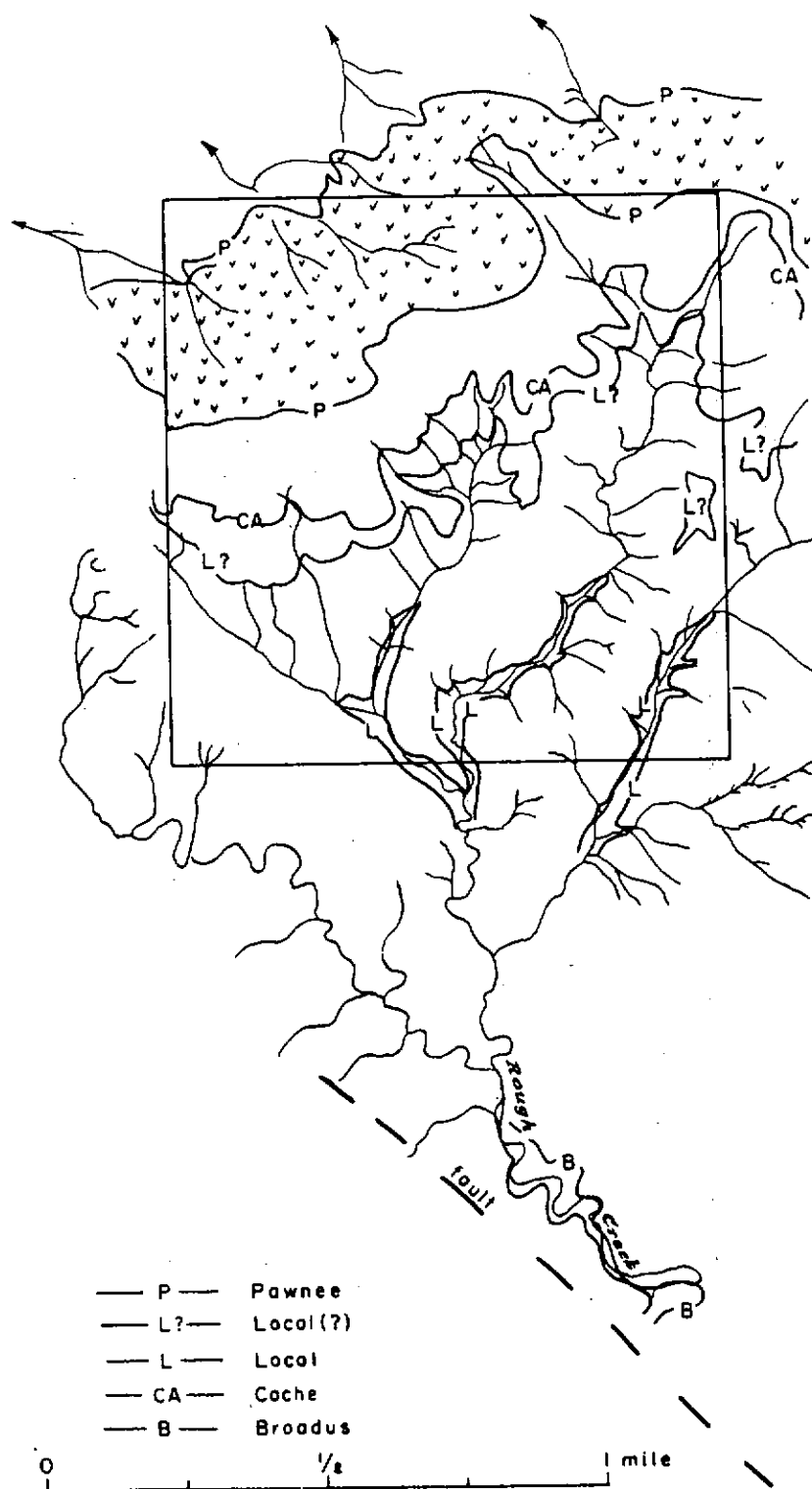


Figure 15. --Sketch map of sec. 16, T. 5 S., R. 50 E.

Broadus Bed. --The Broadus bed is exposed on cut banks in Rough Creek in the southeast quarter of sec. 21. Thicknesses measured by Warren (1959) at two localities in sec. 22 were 10 feet 10 inches and 12 feet 5 inches. At the Superior mine, $1\frac{1}{2}$ miles east of sec. 16, the bed is in two benches separated by a 12-foot parting. The lower bench is 5 feet thick, and the upper bench is 14 feet 4 inches thick.

Local Beds. --The two local beds between the Broadus and the Cache bed are thin and grade laterally into carbonaceous shale. The lower bed was measured in a gully near the southeast corner of sec. 16, as follows:

Feet	Inches	Description
2	0	Coal, abundant previtrain
0	2	Carbonaceous shale
0	6	Coal, abundant previtrain
1	6	Coal and carbonaceous shale alternating in 1-inch layers
0	9	Coal, abundant previtrain

The upper local bed measured near the northeast corner of the SE $\frac{1}{4}$ sec. 16, is 18 inches thick.

Cache Bed. --The Cache bed crops out across the north half of sec. 16. The thickness measured in the northeast quarter of the section is 4 feet 4 inches. The bed grades upward into carbonaceous shale and a fossiliferous zone described under the general description of the Cache coal bed. Good specimens of gastropods and pelecypods were collected from beds above the Cache coal bed in the north-central part of the section.

Pawnee Bed. --The Pawnee bed clinker caps the high divide in the northern part of sec. 16.

Strippable Reserves. --The only appreciable reserves are contained in the Cache coal bed, which underlies 252 acres in sec. 16 and has a reserve of 1,950,000 tons. The two local beds are thin and grade laterally into carbonaceous shale and are not included in the reserve computations.

A possible area of strippable coal of the Broadus bed in sec. 21 and 22 underlies about 200 acres and contains possible reserves of 3 million tons or more.

Sec. 16, T. 6 S., R. 48 E.

Sec. 16, T. 6 S., R. 48 E., lies at the head of the Fire Creek drainage. The relief exceeds 350 feet, altitudes ranging from approximately 3,850 feet, measured in the extreme eastern part of the section, to 4,220 feet, measured in the extreme southwest corner. The section lies on the east flank of the Otter Creek-Powder River divide and south of Pumpkin Creek.

The land is used principally for grazing. Scattered earthenwork reservoirs serve as stock ponds in the area.

An abandoned mine in the adjoining section to the north (SW $\frac{1}{4}$ sec. 9) shows 2 feet of coal. Warren (1959) reported 8 feet of good coal in this same general locality.

Coal Beds. --A local bed, the Canyon bed, and the Garfield bed crop out in this section. The Garfield bed is exposed on the higher ridges near the northern and southern boundaries; 140 to 200 feet below the Garfield bed is the Canyon bed, which crops out in the major drainages. A local bed is exposed approximately 150 feet below the Canyon bed (Fig. 16).

Garfield Bed. --The Garfield bed flanks the northern and southern borders of the section. Where exposed to the south, the Garfield bed consists of thin lenticular coal beds interbedded with carbonaceous shale and is approximately 20 feet thick. The northern outcrop is approximately 5 feet thick and has a carboniferous shale parting 3 feet from the base. A section measured in sec. 9, T. 6 S., R. 48 E., follows:

Feet	Inches	Description
Top		Alluvial mixture of sand and mudstone, dusky yellow
2	2	Coal; abundant gypsum crystals and petrified wood fragments
0	6	Carbonaceous shale, light brown, fissile
3	0	Coal, principally previtrain

Total thickness 5 feet 8 inches

Total thickness of coal 5 feet 2 inches

Canyon Bed. --The Canyon bed crops out throughout the section in the major drainages. It was measured in several places and seems not to exceed 2 feet anywhere in the section. Warren (1959) reported a thickness of 8 feet of coal at an old adit in the SW $\frac{1}{4}$ sec. 9, T. 6 S., R. 48 E., but close examination by the writers reveals that it is predominantly black "carbonaceous" shale capped by 2 feet of coal. This measured section follows:

Feet	Inches	Description
Top		Sandstone, dusky yellow, silty and fine grained
2	0	Coal, mainly previtrain; thin "bony" (clayey) partings
3	0	Carbonaceous shale, brown, fissile
2	0	Carbonaceous shale, black, slightly fissile
0	6	Carbonaceous claystone, brown, slightly silty
4	6	Carbonaceous shale, black

Total thickness 12 feet

Total thickness of coal 2 feet

Other measurements in the section range from 1 foot 2 inches on the eastern border to 2 feet 2 inches in the west-central part.

Local Bed. --The local bed in this area consists of interbedded clay and carbonaceous shale units. The carbonaceous shale grades laterally into very thin lenticular pods of coal.

Reserves. --The Garfield bed may be used as a source of leonardite in the future. The estimated reserve in this area totals 1,954,000 tons.

Garfield Bed. --The average thickness of this bed is 5 feet, the areal extent is 66 acres, and the estimated reserve totals 584,000 tons.

Canyon Bed. --The average thickness is 2 feet, the areal extent is 388 acres, and the estimated reserve totals 1,370,000 tons.

Local Bed. --The local bed is too variable in thickness and is under too much overburden to have any commercial value whatsoever.

Sec. 16, T. 6 S., R. 49 E.

Sec. 16, T. 6 S., R. 49 E., is on the divide between Cache Creek and Fire Gulch. The north half of the section is covered by clinker formed by burning of the Cook bed and supports a moderate growth of pine. The southern half of the section drains into Fire Gulch and has been deeply eroded and dissected. The entire area is used for grazing. Altitude in the section ranges from 4,028 feet near the north quarter corner to 3,606 feet near the south section line at the base of the drainage. A high ridge in the southwest corner of the section is capped by Cook clinker.

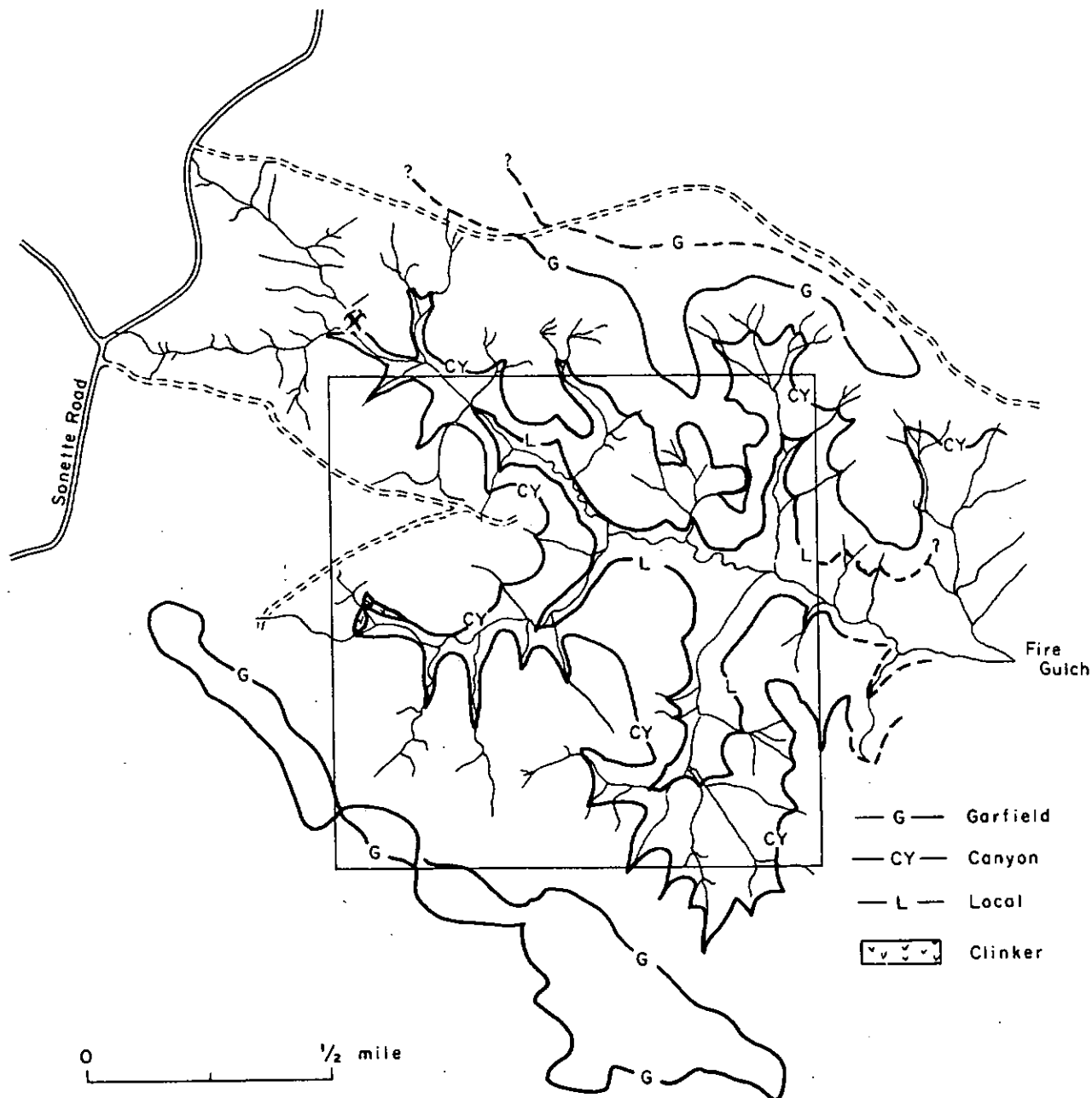


Figure 16. --Sketch map of sec. 16, T. 6 S., R. 48 E.

Coal Beds. --Of the four coal beds in this area, only the Pawnee and a local bed above the Pawnee have potential for recovery. The Pawnee bed is stratigraphically the lowest bed in the area (Fig. 17). The local beds are about 70 feet and 200 feet above the Pawnee bed. The Cook bed is about 375 feet above the Pawnee bed.

Pawnee Bed. --No complete sections of the Pawnee bed were measured. Incomplete measurements in stream cuts in the northern part of sec. 21 averaged 16 feet, and the bed contains abundant previtrain. The 21 feet measured at the Monroe mine in the north-central part of sec. 15, approximately $1\frac{1}{2}$ miles to the northeast, is probably representative. The bed has been burned in a small area in the northwestern part of sec. 21.

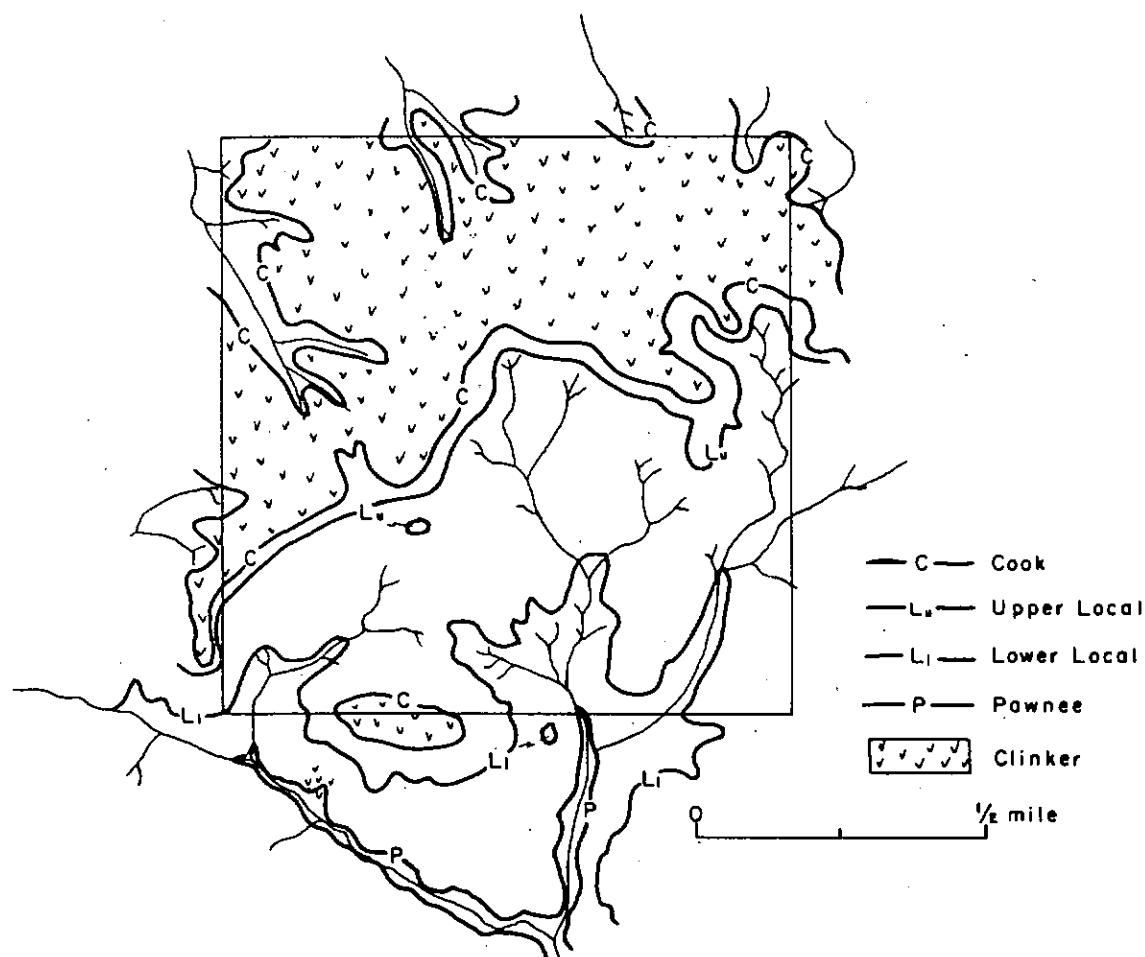


Figure 17. --Sketch map of sec. 16, T. 6 S., R. 49 E.

Local Beds. --The lower local bed was measured in the southeast corner of sec. 17 and in the southeast quarter of sec. 16. The bed changes laterally from interbedded coal and carbonaceous shale to a good coal bed 15 feet thick at the latter locality. A section measured in the southeast corner of sec. 17 follows:

Feet	Inches	Description
4	6	Coal, abundant previtrain
12	6	Carbonaceous shale, gray, abundant gypsum
5	6	Coal, abundant previtrain
0	4	Parting, clay, dark brown
1	6	Coal, abundant previtrain

The local bed has burned along its outcrop in sec. 16, and its clinker caps numerous small isolated knobs.

The upper local bed measured $3\frac{1}{2}$ feet in thickness and is exposed on the sides of the steep bluffs capped by clinker.

Cook Bed. --The Cook bed has burned over most of the area and its clinker covers the ridge tops. Collapse structures from the burning of the underlying Cook bed form two roughly circular depressions on the ridge top in the north-central part of sec. 16.

Coal Reserves. --The coal reserves are in the Pawnee bed and a local bed above the Pawnee. The Pawnee bed underlies the entire section, and the reserves are 18,124,800 tons. The local bed underlies 590 acres, has an average thickness of 13 feet, and contains a reserve of 13,610,000 tons. Reserves for the two beds total 31,734,800 tons.

Sec. 36, T. 6 S., R. 49 E.

Sec. 36, T. 6 S., R. 49 E., borders the Powder River and the Moorhead county road. A minor drainage cuts through the center of the section, exposing three coal beds in its valley walls. Broad, clinker-capped, dissected ridges flank the drainage and give the land a hummocky appearance. The land is used principally for grazing. Two earthen dams in the main drainage provide water for livestock.

Coal Beds. --Three coal beds crop out in this section--a lower local bed, the Cache bed, and an upper local bed. The lower bed is approximately 40 feet below the Cache bed; the upper local bed is 30 to 60 feet above the Cache bed. The Pawnee and Cook beds are exposed north and west of the section (Fig. 18).

Lower Local Bed. --The lower local bed is principally carbonaceous shale in the eastern side of the section, but the coal thickens to almost 11 feet in the northern and western portions. A section measured in the southwest corner follows:

Feet	Inches	Description
Top		Shale, light olive gray, fissile
0	2	Coal, principally previtrain
0	4	Claystone, light olive gray
7	4	Coal, 1-inch clay parting 1 foot 6 inches above base
Base		Underclay, light olive gray

The limits of the coal in this local bed are delineated by partly burnt outcrops.

Cache Bed. --The Cache bed is burned throughout most of the section except the northwest corner. The clinker from burning of the Cache bed caps most of the ridges in the section.

A section measured in the northwest corner of sec. 36 follows:

Feet	Description
Top	Carbonaceous shale, brown, fissile
8	Coal, principally previtrain
Base	Clay, white, slightly silty

Total thickness 8 feet

Total thickness of coal 8 feet

Upper Local Bed. --The upper local bed crops out in the northwest corner of the section. It consists of black to brown fissile carbonaceous shale, which grades laterally to thin lenticular coal. There is no coal of commercial value in this bed.

Pawnee Bed. --The Pawnee bed does not crop out in this section but is exposed in the higher ridges and knolls to the north and west. A section measured near the center of sec. 35 follows:

Feet	Inches	Description
Top		Sandstone, fine to medium grained, cross-bedded; petrified wood
11	6	Claystone, dark olive brown, silty; scattered siderite concretions, nicely preserved leaf impressions
4	8	Coal, weathered previtrain
0	5	Claystone, light brown, slightly fissile; abundant plant fragments
1	0	Coal, weathered
1	1	Carbonaceous shale, dark brown to black, fissile
2	4	Claystone, light gray to brown, slightly silty
1	0	Carbonaceous shale, dark brown to black, fissile
3	2	Sandstone, light yellowish gray to light yellowish orange, silty, some fine-grained sand; scattered siderite concretions
19	1	Coal, principally previtrain
0	4	Carbonaceous shale, light to dark gray
0	5	Coal, principally previtrain, closely cleated
Base		Claystone, light gray to brown, slightly fissile; abundant root fragments

Total thickness 45 feet

Total thickness of coal 25 feet 2 inches

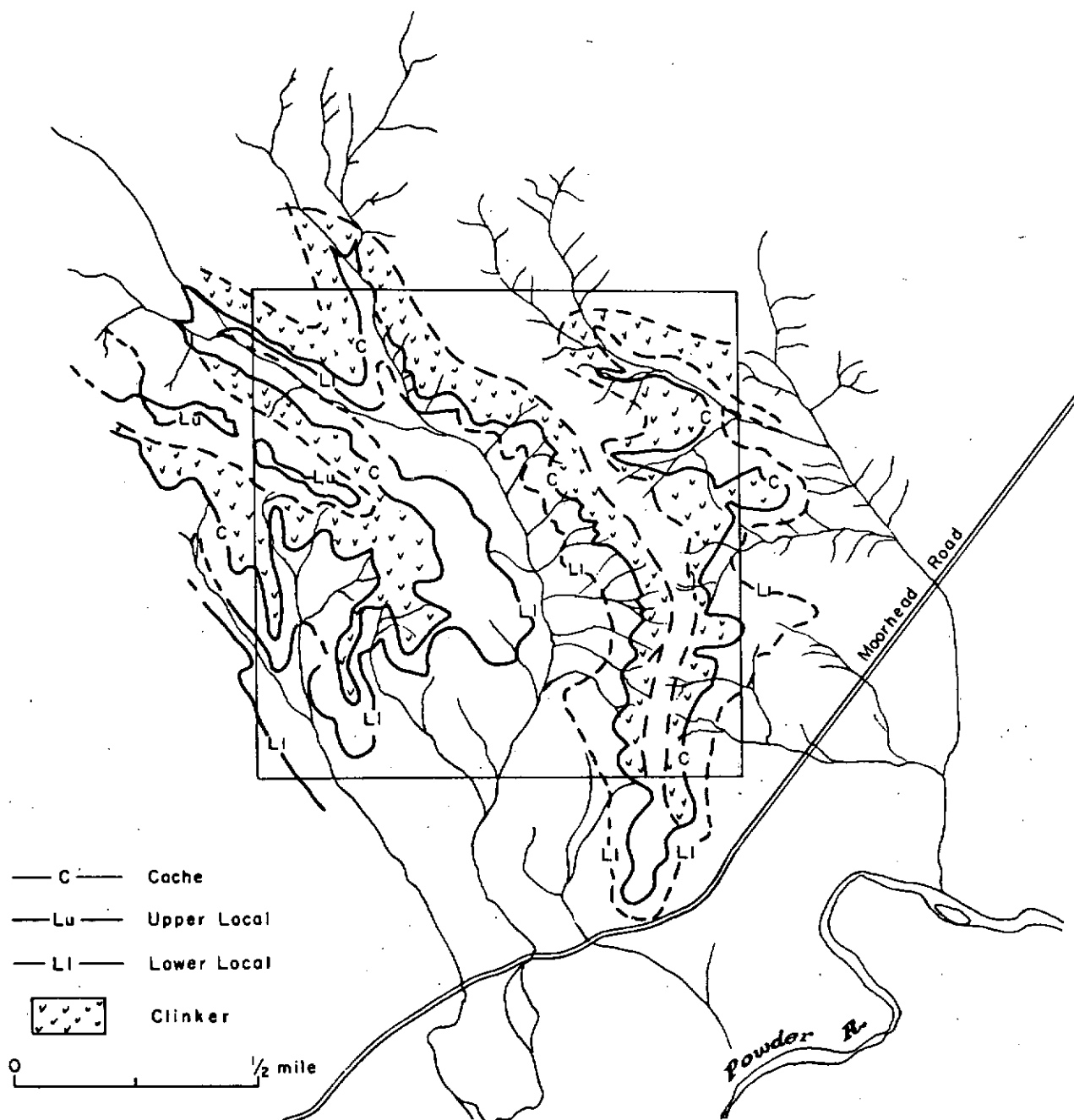


Figure 18. --Sketch map of sec. 36, T. 6 S., R. 49 E.

Cook Bed. --The Cook bed does not crop out in this section, but is extensively burned to the north and west, on the higher clinker-topped buttes.

Reserves. --Estimated reserves for this area total approximately 4,630,000 tons. A breakdown of this total is as follows:

Local bed below the Cache. --The average thickness of this bed is 4 feet and the areal extent is 609 acres. The reserve is 4,310,000 tons.

Cache bed. --The average thickness of the Cache bed in this area is 11 feet, and the areal extent is 14 acres. The reserve is 269,000 tons.

Local bed above the Cache. --The average thickness is 5 feet and the areal extent is 5.5 acres. The reserve is 50,300 tons.

Sec. 16, T. 6 S., R. 50 E.

Sec. 16, T. 6 S., R. 50 E., is on the west side of the Powder River valley about 10 miles southwest of Broadus and is accessible by the Moorhead road, which crosses the section. The land is used entirely for grazing.

High steep ridges capped by clinker occupy the northwest quarter. A massive sandstone below the Cache coal bed forms near-vertical cliffs in places. The eastern half and the southwest corner of the section are covered by alluvium.

There is no strippable coal on the state land, but an area might be developed along the west side of the Powder River valley farther southwest, in sec. 20 and 29.

Coal Beds. --The coal beds exposed include the Broadus, a local bed above the Broadus, and the Cache bed. The Pawnee bed clinker caps a series of high ridges a short distance west of the section (Fig. 19). The local bed is about 270 feet above the Broadus, the Cache bed is about 350 feet above the Broadus, and the Pawnee bed is almost 600 feet above the Broadus bed.

Broadus Bed. --The Broadus bed underlies part of the western half of the section and its clinker is exposed on a few isolated knobs in the northern half of the section west of the Moorhead road. The bed was drilled near the southeast corner of the section, and the log shows a thickness of 6 feet, as follows:

Drill hole SS-1
Collar elevation 3,256 feet
Depth 130 feet

From (ft.)	To (ft.)	Description
0	24	Yellow sand
24	33	Yellow clay
33	35	Soft coal) --Broadus bed
35	39	Hard coal)
39	57	Yellow clay
57	59	Gray clay
59	60	Hard coal

Drill hole SS-1, contd. --

60	69	Gray clay
69	70	Trace coal
70	87	Gray and yellow clay
87	118	Yellow and gray clay
118	122	Gray clay
122	130	Gray sandy clay

The top 2 feet of the Broadus bed is weathered, and the fact that the sediments above the bed are unlike those above the Broadus where it was drilled in sec. 36, T. 5 S., R. 49 E., and farther north in T. 4 S., R. 50 E., indicates that the overburden is alluvium. This relationship further indicates that part of the Broadus bed has been eroded. Approximately $1\frac{3}{4}$ miles northeast, in sec. 10, the measured thickness of the Broadus bed is 11 feet 4 inches.

Local Bed. --The local bed crops out on the steep ridge sides and was measured in two places. In the southwest quarter near the west section line it has thickness of 5 feet 10 inches, and in the northwest quarter

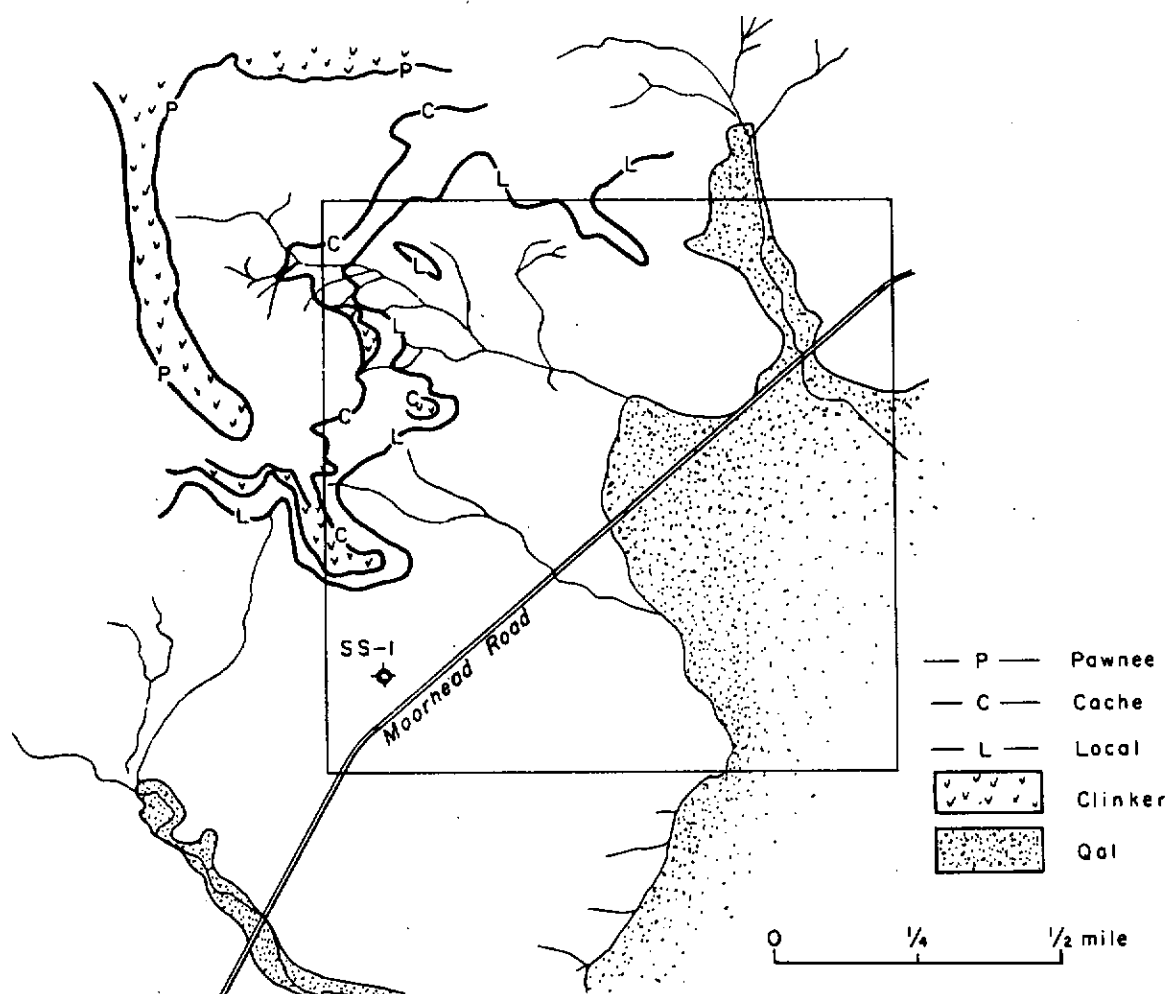


Figure 19. --Sketch map of sec. 16, T. 6 S., R. 50 E.

it has a thickness of 4 feet 10 inches. In the first measured section the bed has two thin partings--a lower 2-inch parting 6 inches above the base of the bed, and an upper 2-inch parting about 6 inches below the top of the bed. In the northwest quarter, the local bed has a 1-inch parting 6 inches above the base.

Cache Bed. --The Cache bed has burned over most of the area, and its clinker caps the lower series of ridges in the western part of the section. The Cache bed, as measured by Warren (1959) in the south-central part of sec. 9, T. 6 S., R. 50 E., is 7 feet 9 inches thick.

Reserves. --There are no strippable reserves in this section. The coal reserves are small and are contained in the Broadus bed, the local bed above the Broadus, and the Cache bed. The local bed underlies 57 acres and contains reserves estimated at 535,000 tons. The reserves of the Cache bed underlie 11 acres and total 136,000 tons. About one quarter of the section is underlain by the Broadus bed, indicating additional reserves of about 1,700,000 tons.

APPENDIX 1, MEASURED STRATIGRAPHIC SECTIONS

Stratigraphic sections were measured by hand level and carpenter's folding rule. In all, more than 950 feet of section was measured. Generally, measurements were taken on prominent cliff faces or steep bluffs where slumping and grass cover were minimal. Although unit numbers were recorded, they are of little use for correlation over a wide area, owing to the limited areal extent of each unit. Sections were measured from coal bed to coal bed, so they could be correlated from place to place.

Cook Bed

Location: NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 31, T. 5 S., R. 50 E.

<u>Unit no.</u>	<u>Thickness (ft.)</u>	<u>Characteristics</u>
135		Cook coal bed
134	13	Interbedded clay stone and sandstone; claystone dusky yellow, slightly silty; sandstone pale olive, silty; claystone diminishes near top of bed
133	12	Interbedded mudstone and sandstone; mudstone yellowish orange, sandy; sandstone yellowish orange, silty, grades to claystone, dark yellowish brown, bentonitic, slightly silty
132	12	Sandstone, light gray, very fine grained, ripple marked
131	3	Mudstone, light gray, very sandy
130	5	Sandstone, light gray, very fine grained; scattered siderite concretions
129	1	Mudstone, ripple marked, moderate brown, siderite cement; very resistant
128	14	Sandstone, ripple marked, very light gray, fine grained, subarkosic, well indurated, limy cement, coalified plant fragments
127	1 $\frac{1}{2}$	Local coal bed
126	1	Carbonaceous shale, grayish black to light brownish gray
125	$\frac{1}{4}$	Claystone, light brownish gray to brownish yellow
124	1 $\frac{1}{4}$	Carbonaceous shale, pale pink
123	27	Claystone, moderate yellowish brown to yellowish gray, extremely bentonitic
122	5	Interbedded sandstone and mudstone; sandstone yellowish gray, fine grained, slightly silty; mudstone orange yellow, sandy; abundant root-lets, scattered siderite zones

Appendix 1, Measured stratigraphic sections, Cook bed, contd.--

<u>Unit no.</u>	<u>Thickness (ft.)</u>	<u>Characteristics</u>
121	1	Sandstone, ripple marked, moderate brown, siderite cement
120	6	Sandstone, ripple marked, light olive gray to pale olive, fine grained, silty, clayey
119	2½	Sandstone, ripple marked, medium brown, very fine grained, siderite cement
118	2½	Sandstone, yellowish gray to grayish orange, medium grained, subarkosic
117	7	Sandstone, yellowish gray to grayish orange, fine grained, fairly resistant
116	6	Sandstone, yellowish gray to grayish orange, medium grained, subarkosic
115	5½	Mudstone, yellowish gray to grayish orange, very sandy, fairly resistant
114	8½	Sandstone, yellowish gray to grayish orange, medium grained, subarkosic
113	3	Claystone, yellowish gray to grayish yellow, silty, laminated

Local Bed

Location: SE¼ SW¼ sec. 4, T. 6 S., R. 49 E.

112	1	Sandstone, dusky yellow, siderite cement, well indurated
111	10	Sandstone, yellowish gray to pale yellowish brown, very fine grained, silty
110	2	Sandstone, dusky yellowish brown, siderite cement, well indurated
109	7	Carbonaceous shale, light gray to light olive gray, thin coal seams, grading laterally to coal
108	3	Clay, medium light gray, bentonitic, grades laterally to carbonaceous shale, abundant selenite (gypsum) crystals
107	3	Claystone, dark yellowish brown, siderite cement, well indurated
106	11	Clay, medium light gray, bentonitic
105	6	Carbonaceous shale, light olive gray, grades laterally to laminated claystone
104	3½	Local coal bed
103	5½	Carbonaceous shale, grayish red, abundant selenite (gypsum) crystals
102	4½	Carbonaceous shale, pale pink to pale olive gray

Local bed, contd.--

Unit no.	Thickness (ft.)	Characteristics
101	6 $\frac{1}{2}$	Carbonaceous shale, light olive gray, grades laterally to local coal bed
100	$\frac{3}{4}$	Sandstone, pale yellowish; scattered siderite concretions
99	$\frac{1}{2}$	Shale, pale yellowish; scattered siderite concretions
98	$\frac{3}{4}$	Sandstone, pale yellowish; scattered siderite concretions
97	4	Claystone, pale yellowish, slightly sandy; scattered siderite concretions
96	15	Sandstone, gray orange to pale light olive gray, very fine grained, silty, high-angle cross-stratification; scattered siderite concretions
95	7 $\frac{1}{2}$	Covered
94	2 $\frac{1}{2}$	Sandstone, pale grayish white, slightly silty and clayey
93	1	Sandstone, gray orange, fine grained
92	2	Sandstone, dark yellowish brown, siderite cement
91	3	Shale, light gray, fairly fissile, slightly sandy
90	3 $\frac{1}{4}$	Claystone, light brown to yellowish gray, sandy
89	$\frac{1}{4}$	Carbonaceous shale, pale pink
88	6	Mudstone, light brown to yellowish gray, intermittent carbonaceous zones

Pawnee Bed

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 5 S., R. 50 E.

87		Pawnee coal bed
86	16 $\frac{1}{4}$	Claystone, pale olive to dark yellowish orange, slightly silty; scattered siderite concretions
85	$\frac{1}{4}$	Local coal seam
84	24	Claystone, light gray to yellowish gray, slightly silty; grades upward to siltstone, pale olive to olive, sandy; siderite concretionary zone at base of unit
83	3	Claystone, pale olive, slightly silty, well indurated; siderite concretionary zone at base of unit
82	11	Claystone, dark yellowish orange to light olive gray, slightly silty; scattered siderite concretionary zones
81	1	Claystone, light gray, slightly silty, well indurated

Appendix 1, Measured stratigraphic sections, Pawnee bed, contd. --

Unit no.	Thickness (ft.)	Characteristics
80	5	Claystone, light olive gray to dark yellowish orange, slightly silty; scattered siderite concretions
79	4	Carbonaceous shale, moderate brown, upper 0.5 foot of unit contains local coal seam
78	6	Mudstone, light olive gray, bentonitic, sandy; numerous selenite (gypsum) crystals
77	5	Sandstone, yellowish gray, fine grained, clayey and silty; scattered siderite concretions
76	6	Sandstone, light olive gray to greenish gray, fine grained, clayey and silty; scattered siderite concretions
75	10	Sandstone, dusky yellow to yellowish gray, medium grained, subarkosic; scattered siderite concretions
74	5	Sandstone, light gray, medium grained, subarkosic
73	15	Sandstone, dusky yellow to yellowish gray, medium grained, subarkosic; scattered siderite concretions
72	4	Sandstone, light gray to dusky yellow, fine grained, high-angle cross-stratification, limy cement, well indurated
71	20	Sandstone, yellowish gray to dusky yellow, slightly bentonitic, very fine to fine grained
70	3	Sandstone, light gray, fine grained, even bedded, limy cement, well indurated
69	23	Sandstone, yellowish gray to dusky yellow, medium grained, subarkosic, slightly resistant, scattered siderite concretions

Cache Bed

Location: SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 5 S., R. 50 E.

68	4	Sandstone, light yellowish brown, subarkosic, thin bedded, high-angle cross-stratification, calcite cement; forms ridge tops locally
67	2	Shale, light olive gray, bentonitic
66	9	Sandstone, light olive gray, very fine grained, silty, poorly sorted
65	11	Carbonaceous shale, light brown, bentonitic; abundant pelecypod fragments
64	3	Claystone, dark yellowish orange

Cache bed, contd.--

Unit no.	Thickness (ft.)	Characteristics
63	12	Carbonaceous shale, light brown to moderate brown; abundant pelecypods and gastropods
62	9	Cache coal bed
61	6 $\frac{1}{2}$	Claystone, pale olive gray, siderite concretionary zone
60	6	Siltstone, medium to moderate brown
59	9 $\frac{1}{2}$	Sandstone, yellowish gray, medium to very fine grained, high-angle cross-stratification; siderite concretionary layers; limy concretionary layer occupies top 3 feet of unit
58	11	Interbedded carbonaceous shale and claystone; carbonaceous shale, moderate brown, claystone yellowish gray
57	1	Carbonaceous shale; black gypsum (selenite) crystals and marcasite balls common
56	16 $\frac{1}{2}$	Interbedded carbonaceous shale and claystone; carbonaceous shale moderate brown, claystone yellowish gray
55	7 $\frac{1}{4}$	Claystone, pale olive, silty; scattered siderite concretions
54	$\frac{1}{4}$	Carbonaceous shale, moderate brown
53	4	Claystone, pale olive, silty
52	1 $\frac{1}{2}$	Sandstone, pale olive, very fine grained
51	4	Claystone, light gray, silty; scattered siderite concretion zones
50	1	Coal (local bed)
49	3 $\frac{1}{2}$	Sandstone, dusky yellow, silty
48	2	Coal (local bed)
47	28	Sandstone, dusky yellow, silty, fine grained
46	20	Sandstone, yellowish gray, fine grained, fairly well sorted
45	$\frac{1}{4}$	Carbonaceous shale
44	5 $\frac{3}{4}$	Interbedded claystone and shale; claystone yellowish gray, shale pale olive; scattered siderite concretions
43	$\frac{3}{4}$	Claystone, moderate brown, siderite cement
42	$\frac{1}{4}$	Carbonaceous shale
41	9 $\frac{1}{2}$	Interbedded claystone and shale; claystone yellowish gray, shale pale olive; scattered siderite concretions
40	$\frac{1}{2}$	Coal (local bed)
39	7	Interbedded claystone and shale; claystone yellowish gray, shale pale olive; scattered siderite concretions

Appendix 1, Measured stratigraphic sections, Cache bed, contd.--

Unit no.	Thickness (ft.)	Characteristics
38	1	Carbonaceous shale, moderate brown
37	7	Interbedded claystone and shale; claystone yellowish gray, shale pale olive; scattered siderite concretion
36	2	Claystone, yellowish gray, silty
35	7½	Sandstone, yellowish gray, silty, very fine grained, limy cement
34	3½	Claystone, grayish yellow, silty; scattered siderite concretion zones
33	5½	Claystone, yellowish gray, silty; scattered siderite concretion zones
32	½	Carbonaceous shale
31	2½	Claystone, purplish brown; leaf imprints
30	½	Carbonaceous shale
29	32	Claystone, grayish yellow, silty; scattered siderite concretions
28	18	Covered
27	1	Carbonaceous shale, sandy
26	6	Covered
25	½	Carbonaceous shale
24	6	Sandstone, pale olive, silty, medium grained, subarkosic
23	27½	Interbedded claystone and sideritic claystone; claystone grayish yellow (silty), sideritic claystone moderate brown
22	1	Shale, yellowish olive
21	2½	Carbonaceous shale, small coal seam near top
20	8½	Claystone, pale greenish yellow, silty, fine bedded
19	1½	Carbonaceous shale, thin previtrain seam near top
18	7	Claystone, pale yellowish green, slightly sandy, well indurated
17	7	Claystone, yellowish gray, silty, thin bedded
16	18	Claystone, yellowish gray, slightly silty, thin bedded; scattered leaf imprints
15	6	Sandstone, massive pale olive to yellowish gray, fine to very fine grained, high-angle cross-stratification; scattered coalified sticks, scattered siderite concretions

Cache bed, contd.--

Unit no.	Thickness (ft.)	Characteristics
14	12	Interbedded sandstone and claystone; sandstone yellowish gray, silty, very fine grained; claystone pale olive, silty; siderite concretions
13	7	Sandstone, pale olive to yellowish gray; scattered siderite concretions
12	5	Interbedded sandstone and claystone, dusky yellow to yellowish gray; sandstone very fine grained, claystone well indurated; scattered siderite concretions

Broadus bed 7.8 feet

Broadus Bed

Location: NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 26, T. 4 S., R. 50 E.

11	85+	Sandstone, fine to medium grained, well sorted, tannish gray, slightly silty, arkosic to subarkosic, high-angle cross-stratification
10	4	Claystone, whitish, bentonitic, scattered olive-color clay pebbles
9	2	Claystone, purplish, well indurated
8	26	Broadus coal bed, clay parting near base of coal
7	24	Interbedded mudstone and silty sandstone; mudstone purple to bluish white, sandstone tan to pale yellowish gray, slightly silty; scattered siderite concretion zones
6	23	Sandstone, tannish gray, arkosic, fine to very fine grained, high-angle cross-stratification; scattered siderite zones
5	1	Carbonaceous shale; thin seam of vitrain near top of unit
4	5	Interbedded claystone and sandstone; claystone yellowish, silty; sandstone tannish gray; scattered siderite zones
3	4	Claystone, whitish blue, bentonitic, slightly silty, varved appearance
2	18	Interbedded siderite and claystone; siderite moderate brown, claystone whitish gray, silty, pebbly appearance
1	35	Sandstone, tannish gray, subarkosic, fine grained, high-angle cross-stratification; claystone pebbles, limonite "ribs" and marcasite "marbles" along bedding planes

APPENDIX 2, PALEONTOLOGY

Fossil mollusks were collected at scattered sites throughout the study area. The best preserved gastropods were sent to the U.S. National Museum, Washington, D. C., for identification.

LOCATIONS

Major localities were $E\frac{1}{2}SE\frac{1}{4}$ sec. 15, T. 5 S., R. 50 E., $NE\frac{1}{4}SW\frac{1}{4}$ sec. 16, T. 5 S., R. 49 E., and $SE\frac{1}{4}$ sec. 27, T. 2 S., R. 49 E. Leaf, wood, and root fragments, as well as poorly preserved mollusks were collected from many clinker or porcelanite exposures.

Locality 1

$E\frac{1}{2}SE\frac{1}{4}$ sec. 15, T. 5 S., R. 50 E., U.S. Geol. Survey Cenozoic Loc. No. 24509. --This is a measured section (App. 1) between the Broadus and Pawnee coal beds. The units (63 and 65) that contain the fossils in this area are predominantly carbonaceous shale and clay, slightly bentonitic.

Mollusks tentatively identified by N. F. Sohl of the U.S. Geological Survey are:

Campeloma nebrascensis (Meek and Hayden)
Plesielliptio priscus (Meek and Hayden)

Locality 2

$NE\frac{1}{4}SW\frac{1}{4}$ sec. 16, T. 5 S., R. 49 E., U.S. Geol. Survey Cenozoic Loc. No. 24510. --This state section has a very small coal reserve but is extremely fossiliferous. The fossils are found predominantly in a light-gray to moderate-brown carbonaceous clay-shale unit. Gastropods less than 10 mm long were collected from anthills, which covered the area in profusion. Vertebrate remains and some recent snails were also collected from the anthills.

Mollusks tentatively identified by N. F. Sohl of the U.S. Geological Survey are:

Paludotrochus retusus (Meek and Hayden)
Campeloma nebrascensis (Meek and Hayden)
Lioplacodes nebrascensis (Meek and Hayden)
Plesielliptio priscus (Meek and Hayden)

Recent land snails were identified as Gyalus parvus (Say), Succinea sp., and Pupilla sp.

Locality 3

SE $\frac{1}{4}$ sec. 27, T. 2 S., R. 49 E., U.S. Geol. Survey Cenozoic Loc. No. 24511. --Although not in the study area, this section is the site of the so-called olive fauna, a Tertiary vertebrate locality. Dr. R. E. Sloan of the University of Minnesota identified the vertebrates as:

Champsosaurus n. sp.

Lepidostens sp.

Anacodon n. sp.

Thryptacodon antiquus

Aspideretes sp.

Entomolestes siegfriedti

Neoplagiaulax n. sp.

Protictus cf. P. haydenianus

Paleosinopa n. sp.

Crocodylus sp.

Plesiadapis dubius

Lamna sp.

Ectypodus powelli

Mesodma silberlingi

Kindleia sp.

Carpolestes nigridentis

Carpolestes aquilae

Phenacolemur jepseni

Haplaletes cf. H. diminutivus

Protentomodon cf. P. ursirivalis

Invertebrate remains identified by Dr. Sloan are:

Lioplacondes limnaeformis (Meek and Hayden)

Lioplacondes nebrascensis (Meek and Hayden)

Campeloma nebrascensis (Meek and Hayden)

Campeloma edmontonensis (Meek and Hayden)

Specimens collected in this locality by the writers were identified as:

Lioplacondes limnaeformis (Meek and Hayden)

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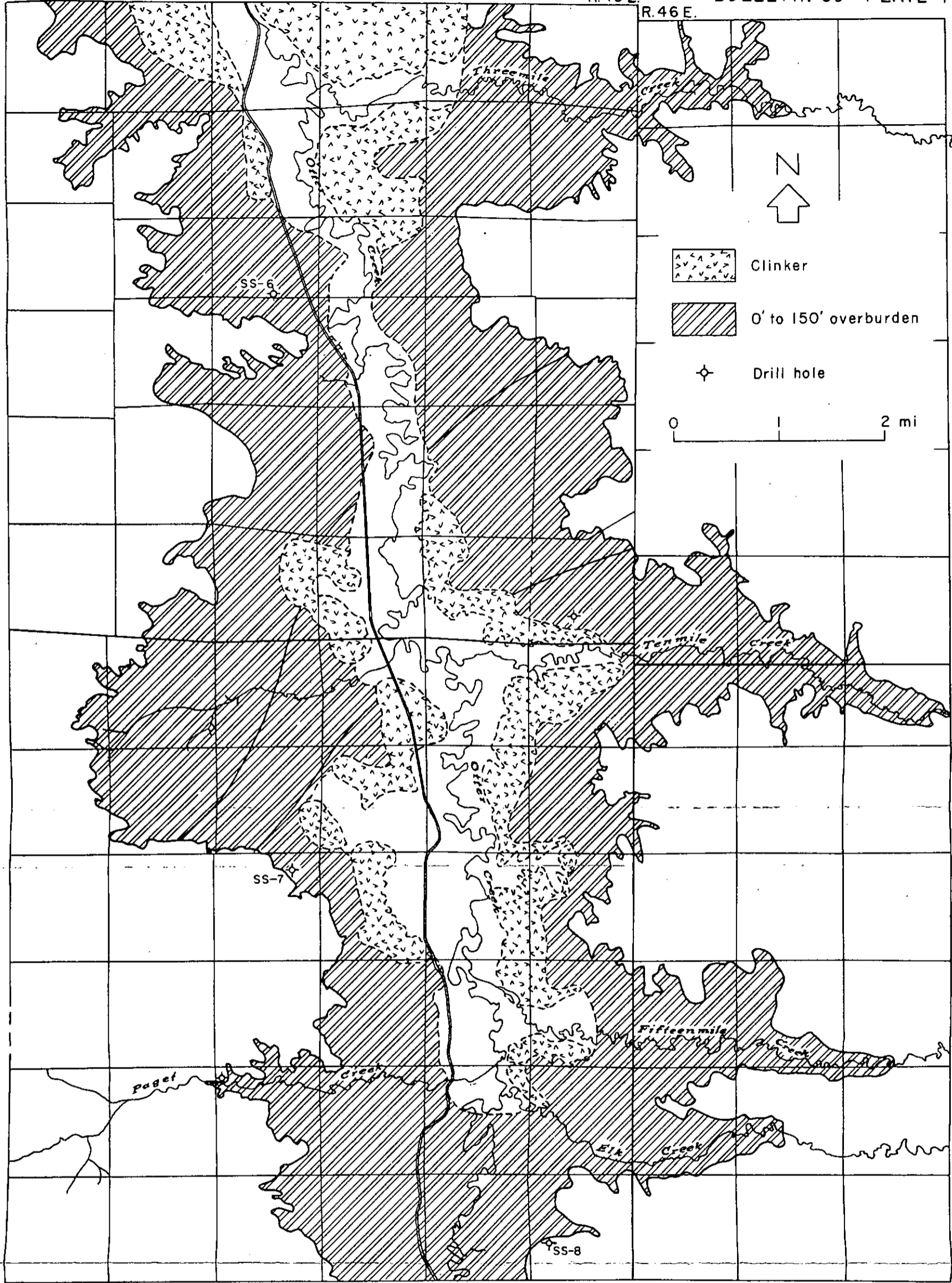
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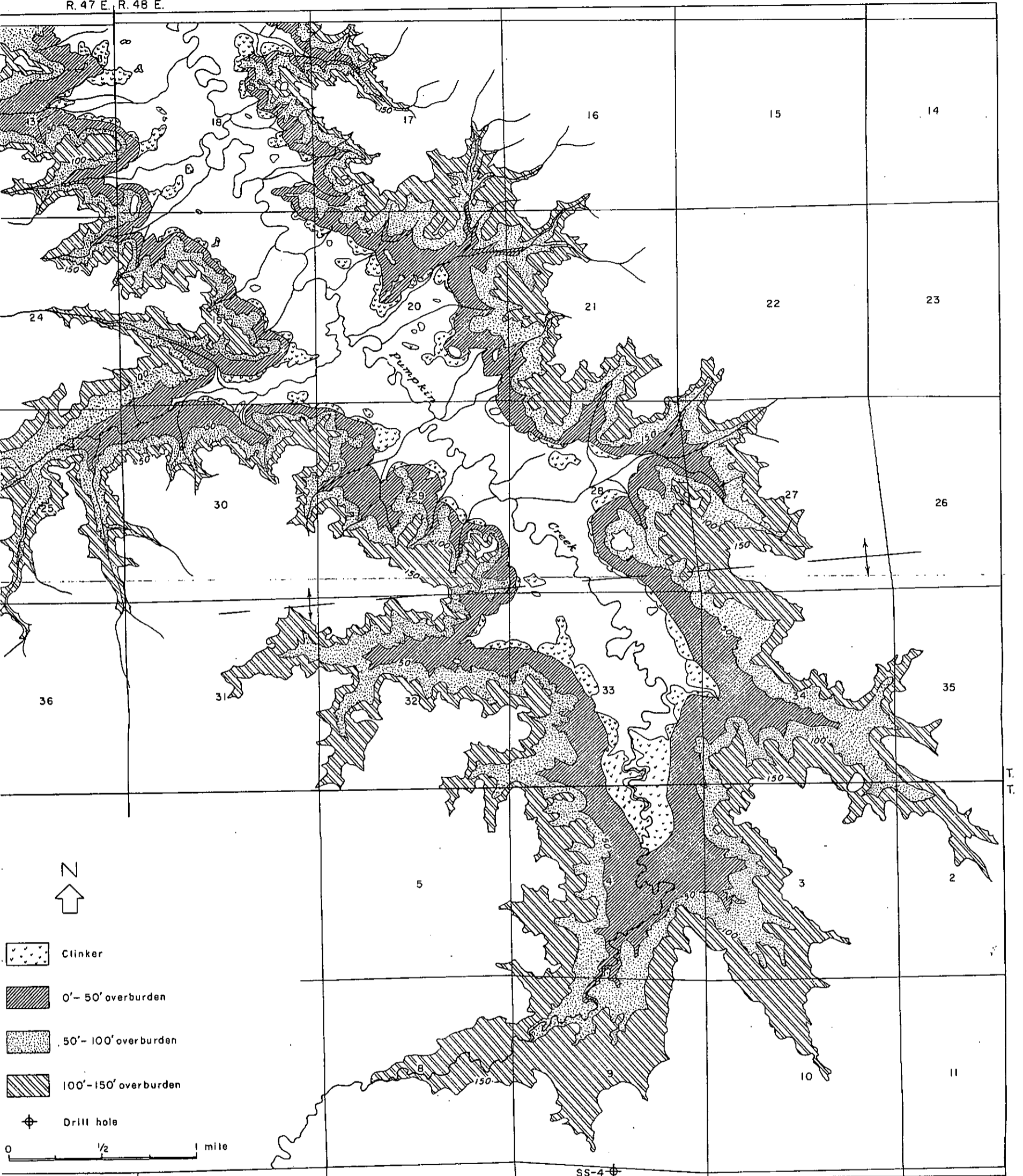
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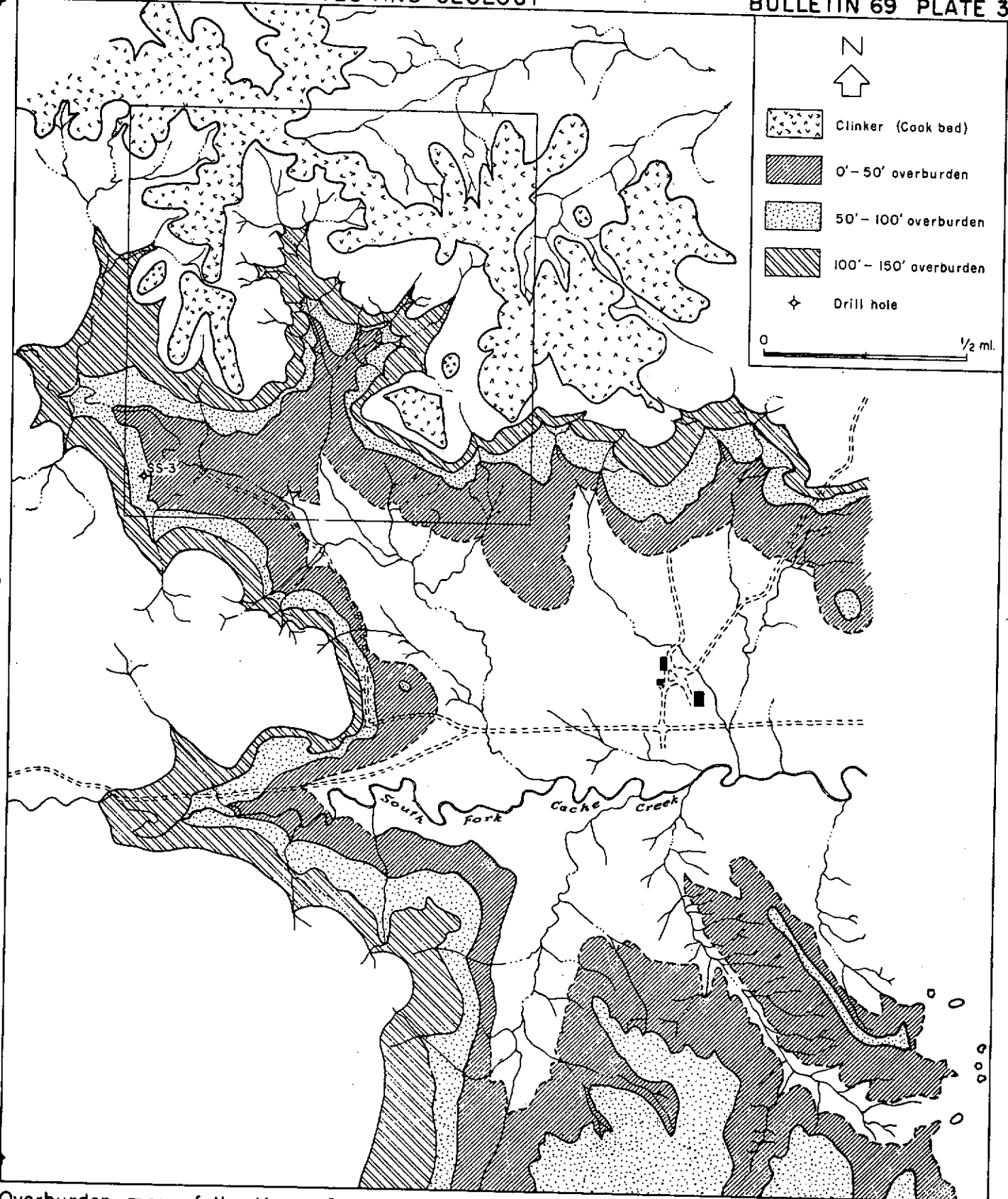
Overburden map of the Otter Creek coal field



OVERBURDEN MAP OF SONNETTE AREA COAL FIELD

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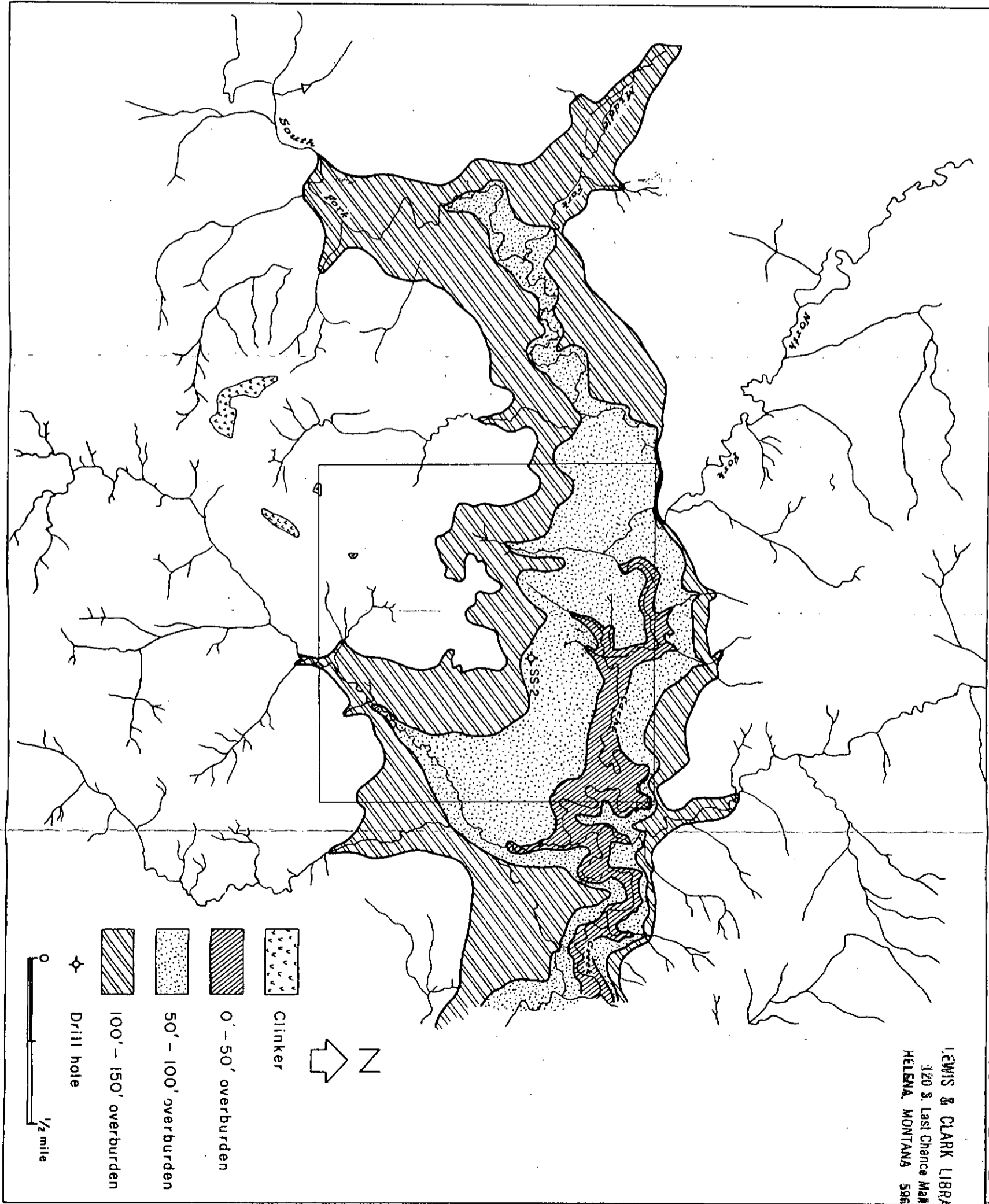


Overburden map of the Upper Cache Creek deposit, sec. 36, T. 5S., R. 48 E., and adjoining area

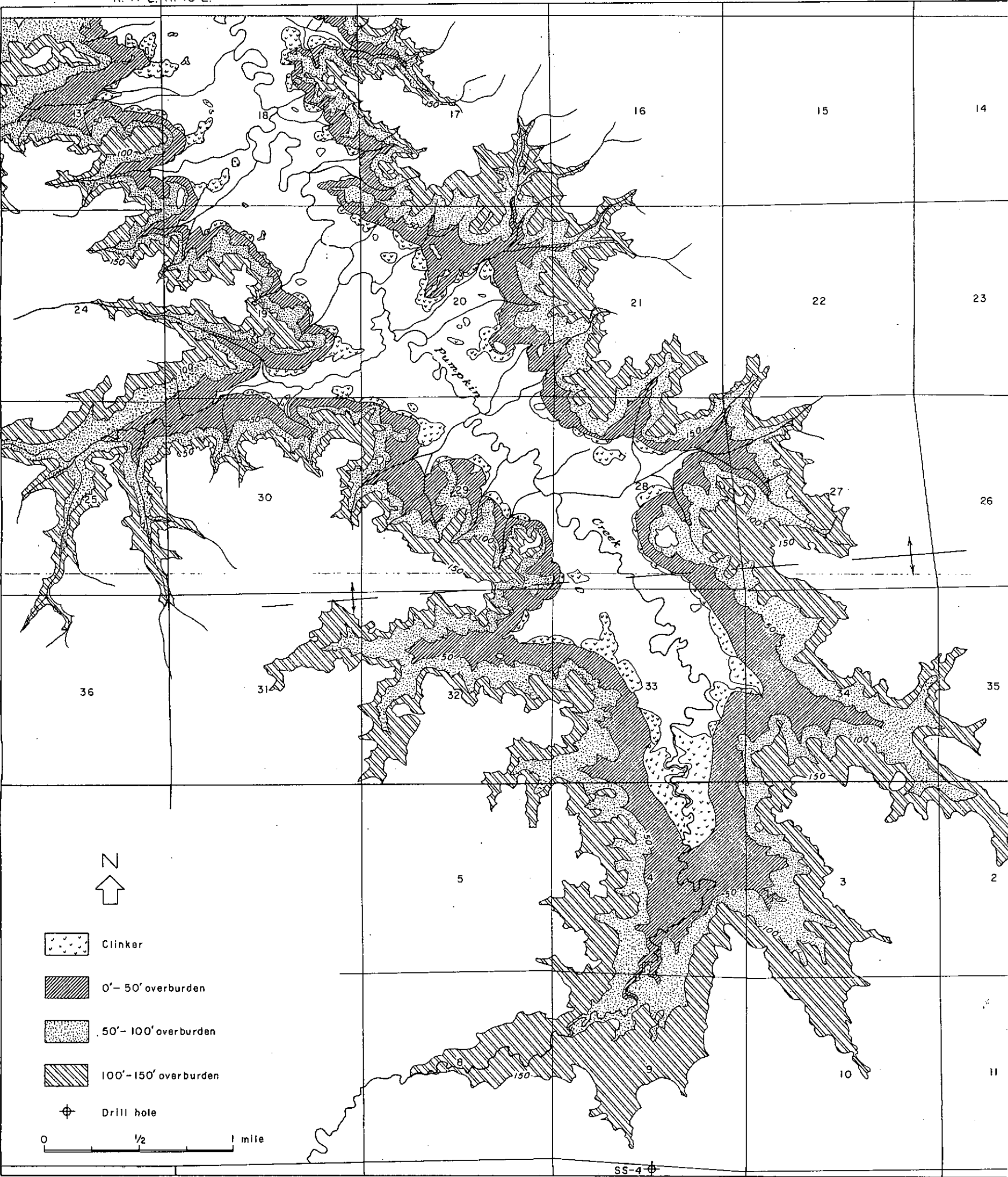
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Overburden map of the Lower Cache Creek deposit, sec. 36, T.5S., R. 49E., and adjoining area



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